Proposal for Wire Tension Requirement

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Factors considered

- Dependence of dE/dx on tension
  - From Tom Junk's talk from last week, this does not seem much of a basis
- Gravitational Sag
  - Not relevant for X (wires vertical)
  - For U or V, 150cm length
    $T = 4\text{N} \rightarrow \delta = 90\ \mu\text{m}$ << position tolerance
  - $\delta \propto \frac{L^2}{T}$
- Electrostatic motion
- Fluid flow

Electrostatics

Instability (wires fan out)

ε_0	8.854E-12	F/m
ε_{LAr}	1.3281E-11	F/m
s	4.79	mm
g	4.75	mm
d	0.1524	mm
C	1.54007E-11	F/m
V	820	V
L	1500	mm
T_C	0.093708046	N

Earlier cm-mm mix up corrected (thanks to Sotiris)

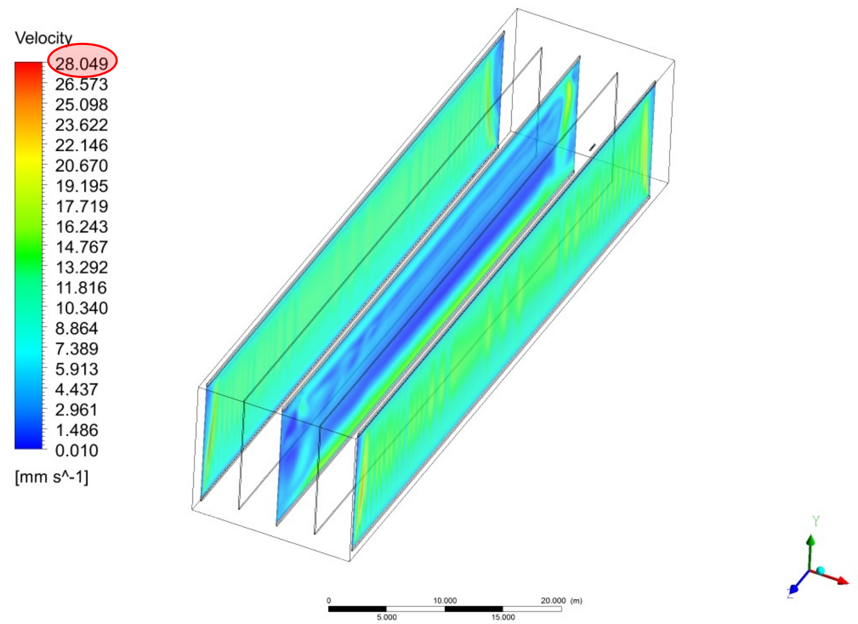
- 4 N is way higher than needed
- $T_C \propto L^2$

Error Amplification

- Nominally zero force
- U, V: unaffected by small placement error (~zero charge on wire)
- X: displacements get amplified
  - Small term – but need to quantify
- Scales as $\frac{L^2}{T}$

Fluid Flow: Static Drag

- Assume 35 mm/sec (higher than normal for APAs)
- ~$4 \cdot 10^{-4}$ N/m
  - Done by Eric from drag on cylinder
  - I get similar result scaling from pressure drop on mesh
- $L = 150\text{cm}, T = 4\text{N}$ $\rightarrow \delta = 3\ \mu\text{m}$
- $\delta \propto \frac{L^2}{T}$

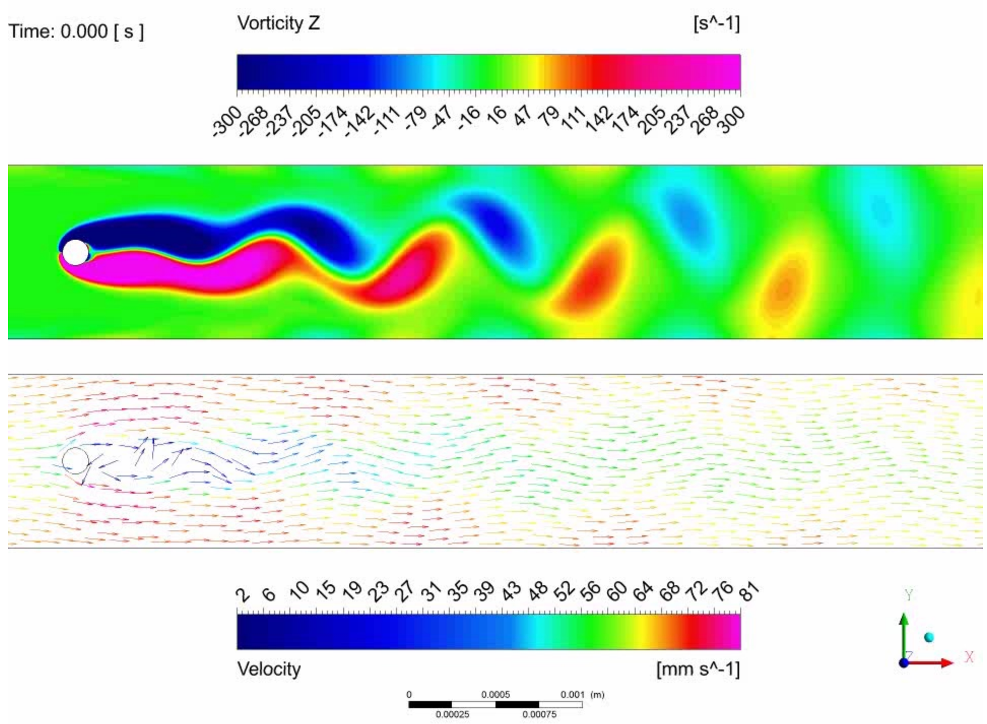


Fluid Flow: Vibration

- CFD from Erik Voirin
- Run mostly at 70mm/s: Velocity around APAs do not go that high
- Short answer
  - Don't expect much single-wire vibration
  - *Might* be significant coherent motion of the entire plane of wires
  - Safest to keep wire resonance (F_{wire}) > von Kármán frequency (F_{vortex})
  - F_{vortex} depends fluid velocity and wire size, but not tension or length
  - $F_{\mathrm{wire}} \propto \frac{\sqrt{T}}{L}$

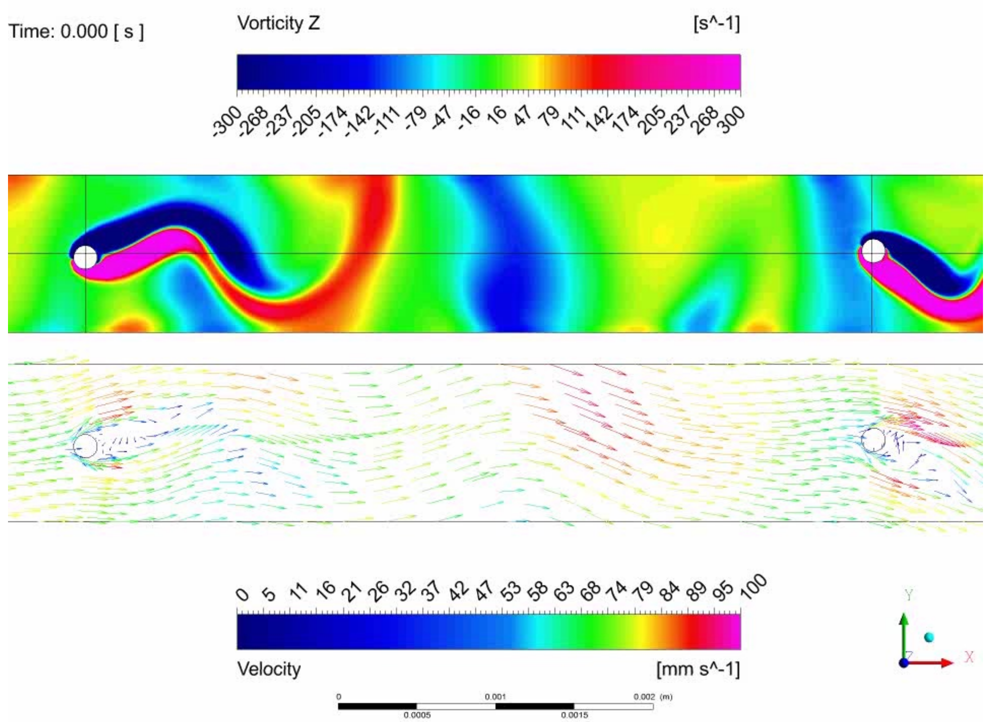
From Erik Voirin

Single wire



Multi-wire vibration

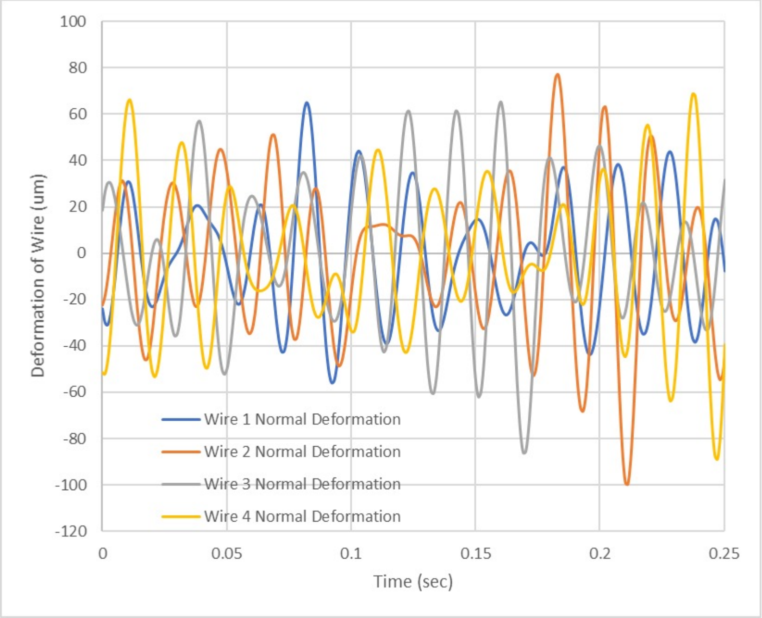
From Erik Voirin



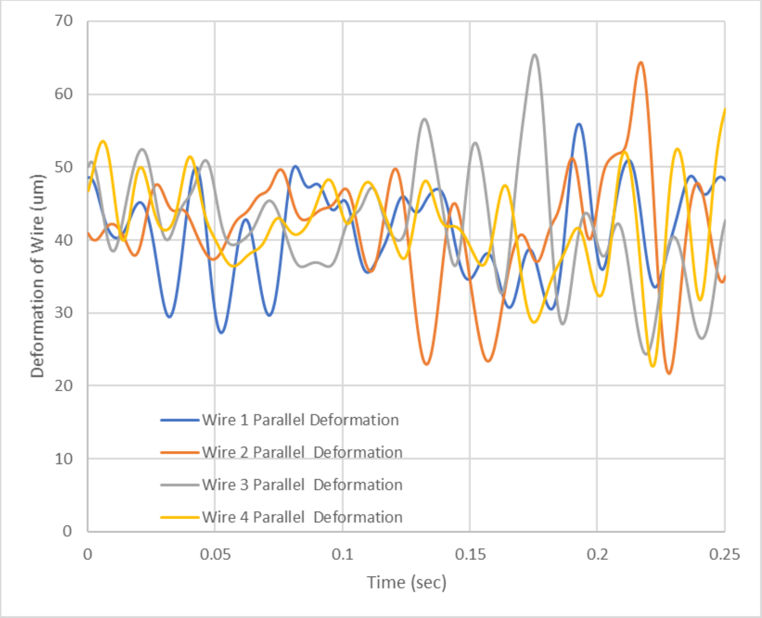
From Erik Voirin

Wire Deformation, 4 Wires

Normal to Flow



Parallel to Flow



CFD Summary

- Tom’s talk showed evidence of coherent motion
  - Would be useful to quantify and feed back to Erik to better understand this phenomenon
- $F_{\text{vortex}} = 58$ Hz @ $V = 70$ mm/s
- $f \propto V$ so more realistic limit on resonance is 29 Hz @ 35 mm/s
- Erik mentions possibly adding more pumps, possibly increasing velocity

Summary

- Lot of affects, no one of which stands out
- In all cases, the relevant term is T/L^2
  Short wire tension can be lower than long wire
- Higher tension → more risk of breaking especially for short wires
- But $T_{\mathrm{min}} \propto L^2$ seems unnecessarily complicated
  - Winding data looks constant tension above 150mm, ~linear below 150mm

Proposal

$$T_{\min} < T < 8.5\mathrm{N}$$

$$T_{\min} = \begin{cases} 4\ \mathrm{N}\ \text{for}\ L \geq 150\mathrm{mm} \\ \dfrac{4\mathrm{N}}{150\mathrm{mm}} L\ \text{for}\ L < 150\mathrm{mm} \end{cases}$$