T1300411 Manifold/Cryopump Baffle blade spring D902817-v4

1/22/13

acceleration of gravity, m/s^2 $g := 9.8$

corrected E factor, based on data from ACB D1002608-v3 sn 001 $\rho := 0.9896$

reduced modulus of elasticity, Pa $E := 186 \cdot 10^9 \cdot \rho$ $E = 1.84066 \times 10^{11}$

modulus of elasticity, psi $E_{psi} := \frac{E}{6895}$ $E_{psi} = 2.66955 \times 10^7$

yield stress of C-250 steel, Pa $S_{yieldms} := 1800 \cdot 10^6$

yield stress of C-250 steel, psi $S_{yieldmspsi} := S_{yieldms} \cdot \left(1.45 \cdot 10^{-4}\right)$

$S_{yieldmspsi} = 2.61 \times 10^5$

Blade Parameters

number of springs $N := 2$

arc of blade spring, rad $\theta_m := \left(\frac{25 \cdot \pi}{180}\right)$

blade arc angle, deg $\theta_{mdeg}(\theta_m) := \theta_m \cdot \frac{180}{\pi}$ $\theta_{mdeg}(\theta_m) = 25$

radius of blade spring, m $R_{bs} := (0.89494)$

radius of blade spring, in $R_{bsin} := \frac{R_{bs}}{.0254}$ $R_{bsin} = 35.23386$

horizontal distance of suspension point from blade spring mount, in $x_{bsin}(\theta_m) := R_{bsin} \cdot \sin(\theta_m)$ $x_{bsin}(\theta_m) = 14.89047$

horizontal distance of suspension point from blade spring mount, m $x_{bs}(\theta_m) := x_{bsin}(\theta_m)\cdot.0254$ $x_{bs}(\theta_m) = 0.37822$

length of blade spring, m $l_{bs}(\theta_m) := R_{bs}\cdot\theta_m$

length of blade spring, in $l_{bsin}(\theta_m) := \frac{l_{bs}(\theta_m)}{.0254}$ $l_{bsin}(\theta_m) = 15.37367$

spring design width, in $bmax_{in} := 4.81274$

Weight suspended

weight of baffle, lbs $m_o := 273.7$ $m_o = 273.7$

fixed balance weights, lbs $m_f := 2\cdot(2.57 + 2.54 + 7.53)$ $m_f = 25.28$

variable balance weights, lbs $m_V := 2\cdot 7.51$ $m_V = 15.02$

weight of total suspended baffle with variable balance weights, lbs $m_{bslb} := m_o + m_f + m_V$ $m_{bslb} = 314$

mass of total baffle, kg $m_{mp}(m_{bslb}) := \frac{m_{bslb}}{2.205}$ $m_{mp}(m_{bslb}) = 142.4036$

mass supported by each blade spring, kg $m_{bs}(m_{bslb}) := \frac{m_{mp}(m_{bslb})}{N}$ $m_{bs}(m_{bslb}) = 71.20181$

load on blade spring, N $P(m_{bslb}) := m_{bs}(m_{bslb})\cdot 9.8$ $P(m_{bslb}) = 697.77778$

Calculate blade spring thickness

$$t(m_{bslb}, bmax_{in}) := \left(\frac{12\cdot P(m_{bslb})\cdot R_{bs}^2}{0.0254\cdot E\cdot bmax_{in}}\cdot\sin\left(\frac{l_{bsin}(\theta_m)}{R_{bsin}}\right)\right)^{\frac{1}{3}}$$

$$t(m_{bslb}, bmax_{in}) = 5.01278\times 10^{-3}$$

thickness of blade spring, in

$$t_{in}(m_{bslb}, bmax_{in}) := \frac{t(m_{bslb}, bmax_{in})}{.0254}$$

$$t_{in}(m_{bslb}, bmax_{in}) = 0.19735$$

FACTOR OF SAFETY

maximum stress, Pa

$$S_{wms} := \frac{E \cdot t(m_{bslb}, bmax_{in})}{2 \cdot R_{bs}}$$

$$S_{wms} = 5.15498 \times 10^{8}$$

maximum stress, psi

$$S_{wspsi} := S_{wms} \cdot 1.45 \cdot 10^{-4} \qquad S_{wspsi} = 7.47473 \times 10^{4}$$

check the factor of safety

$$FS := \frac{S_{yieldms}}{S_{wms}} \qquad FS = 3.49177$$

constant factor, m

$$C(\theta_m, m_{bslb}, b_{in}) := \frac{6 \cdot P(m_{bslb}) \cdot R_{bs}}{S_{wms} \cdot t(m_{bslb}, b_{in})^2}$$

$$C(\theta_m, m_{bslb}, bmax_{in}) = 0.28925$$

$$\frac{C(\theta_m, m_{bslb}, bmax_{in}) \cdot \sin\left(\frac{l_{bsin}(\theta_m)}{R_{bsin}}\right)}{0.0254} = 4.81274$$

Vertical Bounce Frequency

vertical height of suspension from blade spring mount, m

$$y_{bs}(\theta_m) := R_{bs} \cdot (1 - \cos(\theta_m))$$

$$y_{bs}(\theta_m) = 0.08385$$

vertical height of suspension from blade spring mount, in

$$y_{bsin}(\theta_m) := \frac{y_{bs}(\theta_m)}{0.0254}$$

$$y_{bsin}(\theta_m) = 3.30114$$

unloaded height of blade spring, m

$$y_{max} := l_{bs}(\theta_m)\cdot\sin(\theta_m)$$

vertical distance blade moves, m

$$\Delta_y(\theta_m) := y_{max} - y_{bs}(\theta_m) \qquad \Delta_y(\theta_m) = 0.08118$$

vertical distance blade moves, in

$$\Delta_{yin}(\theta_m) := \frac{\Delta_y(\theta_m)}{0.0254} \qquad \Delta_{yin}(\theta_m) = 3.19606$$

vertical resonant frequency based on blade depression, Hz

$$f_{0v}(\theta_m) := \frac{\sqrt{\frac{g}{\Delta_y(\theta_m)}}}{2\cdot\pi} \qquad f_{0v}(\theta_m) = 1.74868$$

BALANCE WEIGHT INCREMENT

effective spring constant, N/m

$$k := \frac{m_{mp}(m_{bslb})\cdot g}{\Delta_y(\theta_m)}$$

$$k = 1.71909 \times 10^{4}$$

incremental force for 15 lb weight change, N

$$\delta F := \frac{15}{2.205}\cdot g$$

height change for 15 lb of added weight, m

$$\delta h := \frac{\delta F}{k}$$

$$\delta h = 3.87802 \times 10^{-3}$$

BLADE THICKNESS VARIATION

baffle balance weight change with δt in change in blade thickness, lbs

$$\Delta m_{\delta tlb}(\Delta t) := m_{bslb}\cdot\left[\left(\frac{t_{in}(m_{bslb}, bmax_{in}) + \Delta t}{t_{in}(m_{bslb}, bmax_{in})}\right)^3 - 1\right]$$

$$\Delta t := 0.001$$

$$\Delta m_{\delta tlb}(\Delta t) = 4.79739$$

alternately, calculate the differential weight change

$$\delta t := 0.001$$

$$\delta m_{\delta tlb}(\delta t) := \frac{(E\cdot bmax_{in})\cdot 2.205\cdot 2}{4\cdot g\cdot R_{bsin}{}^2\cdot \sin\left(\frac{l_{bsin}(\theta_m)}{R_{bsin}}\right)}\cdot t(m_{bslb}, bmax_{in})^2\cdot \delta t$$

$$\delta m_{\delta tlb}(\delta t) = 4.77316$$

Simple Pendulum Frequency

length of pendulum, m $\quad l_{fiw} := 40\cdot 0.0254 \qquad l_{fiw} = 1.016$

pendulum frequency, Hz $\quad f_{0p} := \frac{\sqrt{\frac{g}{l_{fiw}}}}{2\cdot\pi} \qquad f_{0p} = 0.4943$

WIDTH OF BLADE SPRING

blade width at lin from tip, in

$$b(\theta_m, l_{in}, m_{bslb}) := \frac{C(\theta_m, m_{bslb}, bmax_{in})}{.0254}\cdot \sin\left(\frac{l_{in}}{R_{bsin}}\right)$$

blade width at 1/4 from tip, in

$$b\left(\theta_m, \frac{l_{bsin}(\theta_m)}{4}, m_{bslb}\right) = 1.23977$$

$$\frac{l_{bsin}(\theta_m)}{4} = 3.84342$$

blade width at 1/2 from tip, in

$$b\left(\theta_m, \frac{l_{bsin}(\theta_m)}{2}, m_{bslb}\right) = 2.4648$$

$$\frac{l_{bsin}(\theta_m)}{2} = 7.68684$$

blade width at 3/4 from tip, in

$$b(\theta_m, l_{bsin}(\theta_m)\cdot 0.75, m_{bslb}) = 3.66052$$

$$l_{bsin}(\theta_m)\cdot 0.75 = 11.53025$$

max width of blade spring, in

$$b(\theta_m, l_{bsin}(\theta_m), m_{bslb}) = 4.81274$$

$$b_{max}(\theta_m, m_{bslb}) := b(\theta_m, l_{bsin}(\theta_m), m_{bslb})$$

$$l_{bsin}(\theta_m) = 15.37367$$

Solid Works equation

$$x := 0$$

$$R_{bsin} = 35.23386$$

max blade width amplitude, in

$$y_{down}(x) := -5.69426\cdot\sin\left(\frac{x}{35.23386}\right)$$

$$y_{up}(x) := 5.69426\cdot\sin\left(\frac{x}{35.23386}\right)$$

straight line eqtn

$$sl(l_{in}) := \frac{C(\theta_m, m_{bslb}, bmax_{in})\cdot\sin\left(\frac{l_{bsin}(\theta_m)}{R_{bsin}}\right)}{2\cdot 0.0254}\cdot\frac{l_{in}}{l_{bsin}(\theta_m)}$$

Stress at any Cross Section

maximum torque at mount, in-lb

$$\tau_{wall} := x_{bsin}(\theta_m) \cdot m_{bslb}$$

$$\tau_{wall} = 4.67561 \times 10^3$$

stress at x, Pa

$$S(\theta_m, m_{bslb}, x) := \frac{6 \cdot P(m_{bslb}) \cdot R_{bs} \cdot \sin\left(\frac{x}{R_{bsin}}\right)}{.0254 \cdot b(\theta_m, x, m_{bslb}) \cdot t(m_{bslb}, bmax_{in})^2}$$

$$x := \frac{l_{bsin}(\theta_m)}{2} \qquad x := 0.1$$

Stress at position x, Pa

$$S(\theta_m, m_{bslb}, x) = 5.15498 \times 10^8$$

Stress at position x, psi

$$S_{psi}(\theta_m, m_{bslb}, x) := S(\theta_m, m_{bslb}, x) \cdot \left(1.45 \cdot 10^{-4}\right)$$

$$S_{psi}(\theta_m, m_{bslb}, x) = 7.47473 \times 10^4$$

Design Stress at position x, psi

$$S_{wspsi} = 7.47473 \times 10^4$$

summary of design parameters

factor of safety

$$FS = 3.49177$$

weight of baffle plus balance wt, lbs

$$m_{bslb} = 314$$

blade arc, deg

$$\theta_{mdeg}(\theta_m) = 25$$

blade length, in

$$l_{bsin}(\theta_m) = 15.37367$$

thickness, in

$$t_{in}(m_{bslb}) = f(\text{any1\^{}-3}) \rightarrow \text{any1}$$

maximum width, in

$$b_{max}(\theta_m, m_{bslb}) = 4.81274$$

radius of blade spring, in

$$R_{bsin} = 35.23386$$

horizontal distance of suspension point from blade spring mount, in $x_{bsin}(\theta_m) = 14.89047$

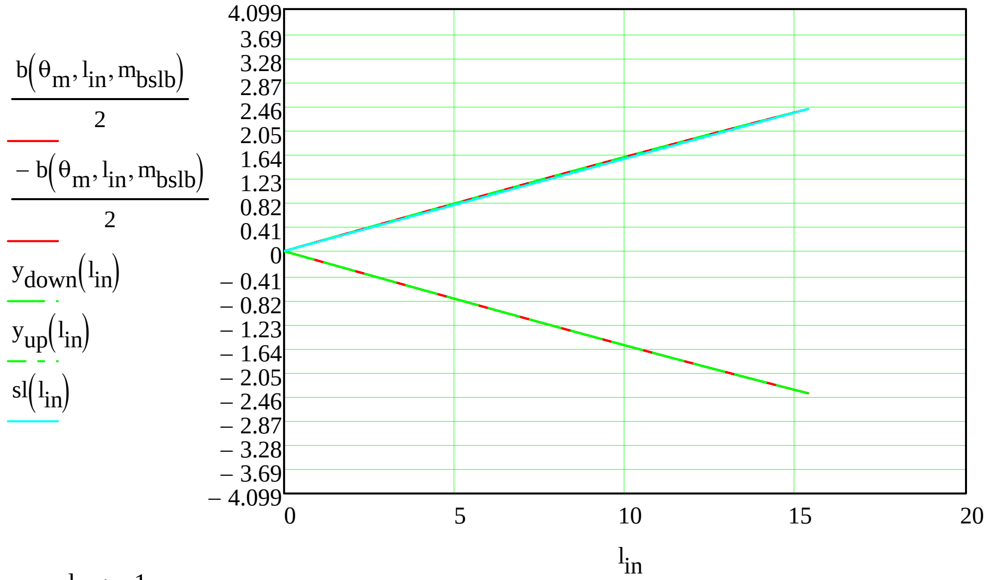
vertical height of suspension from blade spring mount, in $y_{bsin}(\theta_m) = 3.30114$

vertical bounce frequency, Hz $f_{0v}(\theta_m) = 1.74868$

effective spring constant, N/m $k = 1.71909 \times 10^4$

pendulum frequency, Hz $f_{0p} = 0.4943$

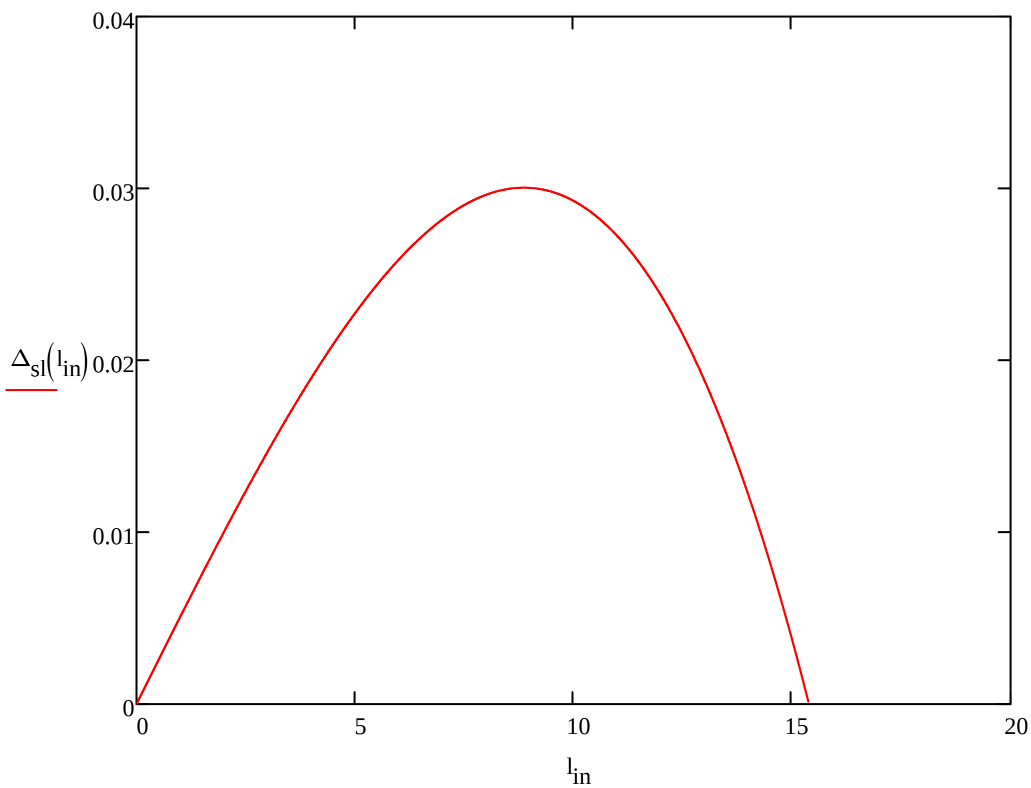
$$l_{in} := 0, 0.001 .. l_{bsin}(\theta_m)$$



$l_{in} := 1$

$l_{in} := 0, 0.001 .. l_{bsin}(\theta_m)$

difference from straight line $\Delta_{sl}(l_{in}) := y_{up}(l_{in}) - sl(l_{in})$



support of baffle with flexure rod

yield stress of C-250 steel, Pa — $S_{yieldms} := 1800 \cdot 10^{6}$

yield stress of C-250 steel, psi — $S_{yieldmspsi} := S_{yieldms} \cdot \left(1.45 \cdot 10^{-4}\right)$

$S_{yieldmspsi} = 2.61 \times 10^{5}$

factor of safety — $FS_{wire} := 31$

working stress of flexure wire, psi — $S_{wpsi} := \frac{S_{yieldmspsi}}{FS_{wire}}$ — $S_{wpsi} = 8.41935 \times 10^{3}$

working stress of flexure wire, Pa — $S_{ws} := \frac{S_{wpsi}}{1.45 \cdot 10^{-4}}$ — $S_{ws} = 5.80645 \times 10^{7}$

number of wires per spring — $N_{w} := 1$

diameter of wire, m — $d_{w} := \sqrt{\frac{4 \cdot m_{bs}\left(m_{bslb}\right) \cdot g}{\pi \cdot S_{ws} \cdot N_{w}}}$ — $d_{w} = 3.91163 \times 10^{-3}$

diameter of wire, in — $d_{win} := \frac{d_{w}}{0.0254}$ — $d_{win} = 0.154$

weight of baffle, lbs — $m_{bslb} = 314$

mass of baffle, kg — $m_{mp}\left(m_{bslb}\right) = 142.40363$

mass supported by each wire, kg — $m_{bs}\left(m_{bslb}\right) := \frac{m_{mp}\left(m_{bslb}\right)}{N}$ — $m_{bs}\left(m_{bslb}\right) = 71.20181$

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