Table of Inputs and Outputs
Dynamic Optimization of Tensegrity Systems

Shyam Patel

May 5, 2020

Optimizer Input

Input	Range	Explanation
p	4 - 8	Number of units in the circumferential direction
q	4 - 8	Number of units in the vertical direction
L	0.5 - 1 m	Vertical length of structure
r_{ss}	0.0005 - 0.0025 m	Radius of surface strings
r_{si}	0.0005 - 0.0025 m	Radius of internal strings
r_b	0.0001 - 0.005 m	Radius of bars
C_2	-0.1 - 0.1	Concentration of vertical units
N_z	-0.4 - 0.4	Position of central load
$2R/L_{rcc}$	0.5 - 3.0	Ratio of diameter to length - cylinder
$2R/L_{por}$	0.5 - 3.0	Ratio of diameter to length - paraboloid
$2R/L_{elp}$	0.25 - 1.5	Ratio of diameter to length - ellipsoid
g_{max}	10 g	Max g-force ceiling

Environment Input

Input	Value	Explanation
h	1 m	Initial distance between bottom node and ground
v_0	-10 m/s	Initial vertical velocity
m_{load}	20 kg	Mass of central payload
g	-9.81 m/s^2	Earth gravity
θ_y	0:π/6:π/2	Rotations about y-axis
$\theta_{x_{sp}}$	0:π/18:π/9	Rotations about x-axis for sphere
$\theta_{x_{rcc}}$	0:π/18:π/9	Rotations about x-axis for cylinder
$\theta_{x_{por}}$	0:π/18:π/9	Rotations about x-axis for parabola

Environment Output

Output	Explanation
m	Total system mass
g_s	Max acceleration in G's experienced by system
σ_{ss_d}	Max stress exceeding surface string limit
σ_{si_d}	Max stress exceeding internal string limit
σ_{bc_d}	Max stress exceeding bar compressed stress limit
σ_{bt_d}	Max stress exceeding bar tension stress limit
V_c	Volume constraint magnitude

Material Properties

Density of strings and bars	$\rho_s = 1123$ kg/m^3, $\rho_b = 4705$ kg/m^3
Elastic modulus of strings and bars	$E_s = 1 \times 10^8$ Pa, $E_b = 60 \times 10^9$ Pa
Damping coefficient of strings and bars	$c_s = 5 \times 10^6$ Pa, $c_b = 0$ Pa

Bar Material - Titanium

String Material - Nylon

Optimization Function

$$f = m + p_g + p_{\sigma_{ss}} + p_{\sigma_{si}} + p_{\sigma_{bc}} + p_{\sigma_{bt}} + p_{V_c}$$

Where:

$$p_i = \lambda_i * \gamma_i$$

λ_i is the conditional multiplier based on the magnitude of the fitness error.
n_i Normalizes the fitness function errors.

Where:

$$\begin{aligned}\gamma_g &= 1^{12}\\ \gamma_{\sigma_{ss}} &= 1\\ \gamma_{\sigma_{si}} &= 1\\ \gamma_{\sigma_{bc}} &= 1\\ \gamma_{\sigma_{bt}} &= 1\\ \gamma_{V_c} &= 1^{14}\end{aligned}$$

and,

$$\lambda_g = \begin{cases} 0, & \text{if } g_s \leq g_{max} \\ (g_{max} - g_s)^2, & \text{if } g_s \geq g_{max} \end{cases}$$

$$\lambda_{\sigma_{ss}} = \begin{cases} 0, & \text{if } \sigma_{ss} \leq \sigma_{ss_{max}} \\ (\sigma_{ss_{max}} - \sigma_{ss})^2, & \text{if } \sigma_{ss} \geq \sigma_{ss_{max}} \end{cases}$$

$$\lambda_{\sigma_{si}} = \begin{cases} 0, & \text{if } \sigma_{si} \leq \sigma_{si_{max}} \\ (\sigma_{si_{max}} - \sigma_{si})^2, & \text{if } \sigma_{si} \geq \sigma_{si_{max}} \end{cases}$$

$$\lambda_{\sigma_{bc}} = \begin{cases} 0, & \text{if } \sigma_{bc} \leq \sigma_{bc_{max}} \\ (\sigma_{bc_{max}} - \sigma_{bc})^2, & \text{if } \sigma_{bc} \geq \sigma_{bc_{max}} \end{cases}$$

$$\lambda_{\sigma_{bt}} = \begin{cases} 0, & \text{if } \sigma_{bt} \leq \sigma_{bt_{max}} \\ (\sigma_{bt_{max}} - \sigma_{bt})^2, & \text{if } \sigma_{bt} \geq \sigma_{bt_{max}} \end{cases}$$

$$V_c = \begin{cases} 0, & \text{if } V_c \leq V_{c_{max}} \\ (V_{c_{max}} - V_c)^2, & \text{if } V_c \geq V_{c_{max}} \end{cases}$$