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Engaged 2015

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Characteristics of the flexible Tsunami Barbell

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What is a Tsunami Bar?

- FLEXIBLE, WEIGHT LIFTING BARBELL, Available in different SIZES and MATERIAL PROPERTIES
- Use: RESISTANCE TRAINING by ATHELETS and NON ATHELETS.
Goals

- 3D DATA COLLECTION AND ANALYSIS
- USE RESULTS TO CHARACTERIZE the TSUNAMI BAR WITH **MASS-SPRING-DAMPER** MODEL
  - CALCULATE SPRING CONSTANT
  - CALCULATE DAMPING COEFFICIENT
MATHEMATICAL MODEL

SPRING MASS SYSTEM

\[ \frac{d^2x}{dt^2} + 2\zeta \omega_0 \frac{dx}{dt} + \omega_0^2 x = 0, \]

2\textsuperscript{nd} Order differential equation

<table>
<thead>
<tr>
<th>Spring constant</th>
<th>Natural Frequency</th>
<th>Damping coefficient</th>
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<tr>
<td>‘k’</td>
<td>( \omega_0 = \sqrt{\frac{k}{m}} )</td>
<td>( \zeta = \frac{c}{2\sqrt{mk}} )</td>
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Types of Bar used

- Black flex PVC, inner radius ¾” (Highly Damped)
- White rigid PVC, inner radius ¾” (Highly Damped)
- Beige CPVC, inner radius ½” (Highly Damped)
Cross-Section of the Bar.

- Fiber Glass Rectangular Bars
- Fiber Glass Circular Bar

Properties
- Lightly Damped
Hooke’s law

- $F = -kx$, FORCE DIRECTLY PROPORTIONAL TO DISPLACEMENT
- $F =$ FORCE APPLIED, $x =$ DISPLACEMENT and
- $K =$ SPRING CONSTANT.
Black flex PVC

Displacement in cm vs. Weight

\[ y = 4.7036x \]
\[ R^2 = 0.9514 \]
Comparative Spring Constant

- Black flex PVC 3/4" spring constant: 188.65 N/m
- Beige rigid CPVC .5" spring constant: 302.74 N/m
- White rigid PVC 3/4" spring constant: 618.3 N/m

Equation: $y = 214.83x - 59.753$

$R^2 = 0.9317$
MOTION CAPTURE DEMONSTRATION
DAMPING COEFFICIENTS

- Critical damping ($\zeta = 1$)
- Over-damping ($\zeta > 1$)
- Under-damping ($0 \leq \zeta < 1$)
Black Flex Motion

Displacement in mm

Time in seconds
Comparative motion of the Bars

Displacement in mm vs. Time in seconds for Black flex PVC, White rigid PVC, and Beige Rigid CPVC.
SOLUTION

For successive amplitudes \( m = 1 \)

\[
\ln\left( \frac{x_1}{x_2} \right) = \ln\left( \frac{3}{0.5} \right) = \ln 6 = 1.792 = \text{amplitude reduction factor}
\]

\[1.792 = \frac{2\pi \delta}{\sqrt{1 - \delta^2}} \quad \text{square both sides}\]

\[3.21 = \frac{39.478\delta^2}{1 - \delta^2} \quad \text{so} \quad 1 - \delta^2 = 12.298\delta^2\]

\[13.298\delta^2 = 1 \quad \text{and} \quad \delta^2 = \frac{1}{13.298} = 0.075 \quad \text{and} \quad \delta = \sqrt{0.075} = 0.274\]
DAMPING COEFFICIENT

Damping Coefficient

- Black Flex: 0.0653
- White hard: 0.0335
- Beige hard: 0.0352
FUTURE RESEARCH AND GOALS

Forced Oscillations

Newton's 2nd Law terms

\[ m \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = F_0 \cos(\omega t + \varphi_d) \]

Sinusoidal driving force

- OPTIMUM VELOCITY, RANGE OF MOTION
- DISTANCE OF WEIGHT FROM THE BAR
- COMPREHENSIVE MODEL
QUESTIONS OR COMMENTS.