Millipede KineticKit™

Millipede Bar Group 3

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Agenda

- Introduce Problem

- Introduce Solution

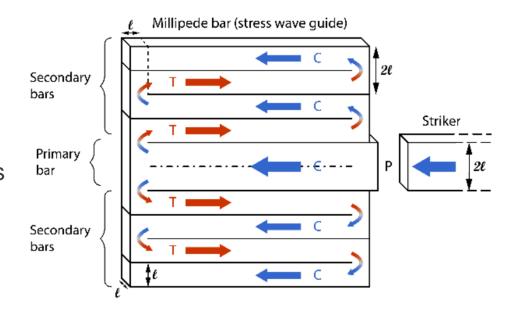- Product Features

- Design Specifications

- Manufacturing and Design Changes

- Costs and Mass Production

- Current Obstacles and Next Steps

- Why Choose Our Product

Problem

- Goals:
  - Design a millipede bar system that transfers long duration square stress pulses around 180-degree bends
  - Implement boundary conditions to minimize loss in stress wave amplitude
  - Manufacture testing system to prove/disprove concept
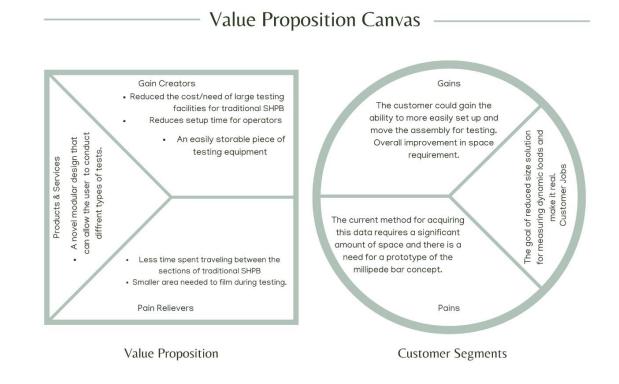
Problem/Target Market

- Problem: Current Dynamic Devices are massive in size (up to a mile long) and no alternative

- Market: Materials Research Sector (Public and Private) and Academia

- The requested apparatus is in the form of a millipede bar, where boundary conditions are met to ensure reliable data.

Solution: Hedgehog Aspects

- Our design is an adaptable cost-effective dynamic testing system.
  - The proposed design is adaptable, meaning one design can give solutions to a variety of customers.
  - The proposed design is simple, with few moving parts and an easily manufactured 2D millipede bar.
  - The proposed design is cost effective, more budget friendly compared to competitors.

Value Proposition

- Customer Need for smaller scale

- Customer Need for scalability/mass product quantities

- Customer Need for a cost-effective alternative

Value Proposition Canvas

Gain Creators
- Reduced the cost/need of large testing facilities for traditional SHPB
- Reduces setup time for operators
- An easily storable piece of testing equipment

Products & Services
- A novel modular design that can allow the user to conduct diffrent types of tests.

- Less time spent traveling between the sections of traditional SHPB
- Smaller area needed to film during testing.

Pain Relievers

Value Proposition

Gains

The customer could gain the ability to more easily set up and move the assembly for testing. Overall improvement in space requirement.

The goal of reduced size solution for measuring dynamic loads and make it real.

Customer Jobs

The current method for acquiring this data requires a significant amount of space and there is a need for a prototype of the millipede bar concept.

Pains

Customer Segments

Artifact Demonstration

- Artifacts were prototyped to show proof-of-concept for the proposed solution

Solution: Product Overview

- *Spring launching mechanism for variable striker bar velocity*

- *Plexiglass 2D millipede bar for cost-effective testing*

- *Base plate and shim stock in between bends to ensure boundary conditions met*
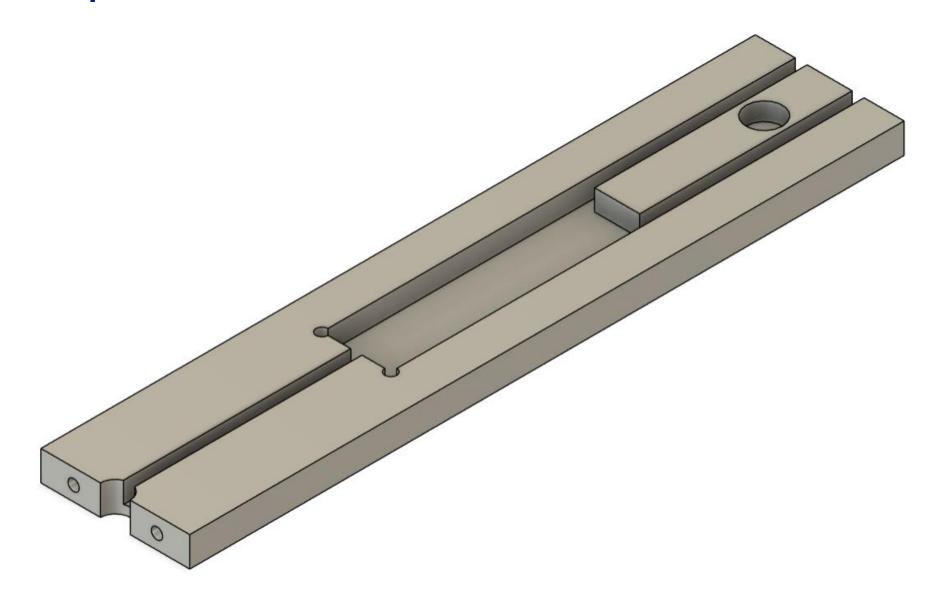
- *Aesthetic housing to ensure user safety*

Solution: Product Overview

Omitted to ensure stable Canvas Submission

Millipede Bar Housing
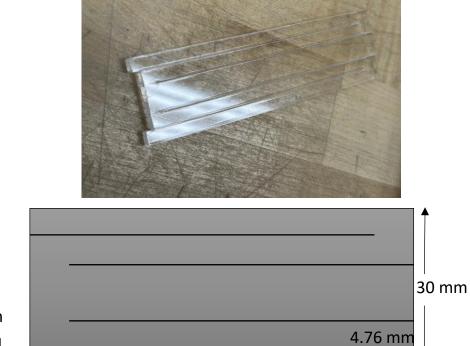
Millipede Bar Plate

Spring Launched Striking Mechanism

Design Geometry

- Plexiglass Specifications:
  - $\rho = 1.18 \text{ kg/m}^3$
  - $E = 8.79 \text{ MPa}$
  - $v = \sqrt{\dfrac{E}{\rho}} = 2730 \text{ m/s}$

- Millipede Bar Specifications:
  - $L = 100 \: mm$
  - $W = 30 \: mm$
  - Cross Section Dimensions: $4.76 \text{ mm} \: x \: 4.76 \text{ mm}$

4.76 mm

4.76 mm

30 mm

4.76 mm

100 mm

- Striker Bar/Transmission Bar Specifications:
  - $L = 100 \: mm$
  - Cross Section Dimensions: $4.76 \text{ mm} \: x \: 4.76 \text{ mm}$

4.76 mm

4.76 mm

100 mm

Fulfilling Design Specifications

$$l = 4.78 \text{ mm}$$

$$L = 100 \text{ mm}$$

$$\Lambda = 100 \text{ mm}$$

$$v = 2730 \frac{\text{m}}{\text{s}}$$

$$t_p = \frac{2\Lambda}{v} = \frac{2 \times 0.1 \text{ m}}{2730 \frac{\text{m}}{\text{s}}} = 7.33 \times 10^{-5} \text{ s}$$

$$t_j = \frac{l}{v} = \frac{0.00478 \text{ m}}{2730 \frac{\text{m}}{\text{s}}} = 1.75 \times 10^{-6} \text{ s}$$

$$T^* = \frac{t_p}{t_j} = \frac{7.33 \times 10^{-5} \text{ s}}{1.75 \times 10^{-6} \text{ s}} = 41.84$$

$$T^* = 41.84 > 30$$

$$\frac{L}{l} = \frac{100 \text{ mm}}{4.78 \text{ mm}} = 20.92 < 100$$

Spring Analysis

- Spring Mechanism:
  - Using Conservation of momentum, the required springs for each striker speed was found.
  - Alternatively, the distance was varied to test the feasibility of varying the distance with the same spring
  - Ultimately a constant draw distance was chosen.
  - The assembly will ship with ten total springs that can be switched out easily for each speed that is needed.
  - Through testing it was found that the math did not account for friction and additional losses.

Striker Speed (m/s)	Distance Required (in)
1	0.05
2	0.10
3	0.15
4	0.20
5	0.25
6	0.30
7	0.35
8	0.40
9	0.45
10	0.50

Striker Speed (m/s)	Spring Constant (N/m)	Spring Constant (lb./in)
1	3	0.02
2	9	0.05
3	20	0.11
4	36	0.21
5	57	0.33
6	82	0.47
7	111	0.63
8	145	0.83
9	183	1.05
10	226	1.29

Factor of Safety of the Roll Pin

$$k_{max} = 15 \frac{lb}{in}$$

$$F_{spring} = k \times \Delta x$$

$$F_{spring} = 15 \frac{lb}{in} \times 0.5 \; in = 7.5 \; lb$$

$$\sigma = \frac{F_{spring}}{A_{Pin}} = \frac{7.5 \; lb}{0.08 \; in \times 0.25 \; in} = 375 \; psi$$

$$\sigma_{y_{steel}} = 31200 \; psi$$

Well within factor of safety requirements

Manufacturing

- Spring Launcher Assembly manufactured by Garrett Bryant using his own tools and materials

- Millipede Bar Plate manufactured using in house CNC

- Millipede Bar and Striker Bar manufactured using a laser cutting machine with the help of the FAB Lab located at Infinity Hall

- Housing Structure planned to be manufactured using 3D printed material

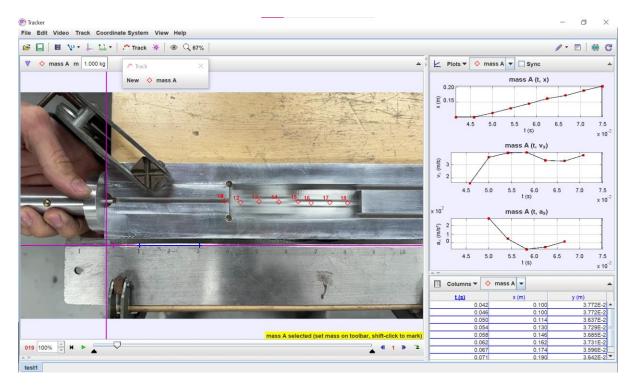- All other aspects of the design are OTS parts

Fabrication Progress

- Subsystems are at different levels of completion:

Item	Status
Millipede Bar	Complete
Base Plate	Technician Difficulties
Box Housing	Awaiting Base Plate Completion; Attempt was made within timeframe available
Striking System	Complete
Final Assembly	Awaiting Subsystem Completion

Design Changes

- Spring testing through video analysis showed differences between theoretical and physical spring constant-striker velocity relationship

- Yielded a roughly $1 \frac{lb}{in} \sim 1 \frac{m}{s^2}$ proportion

Design Changes

- 10 springs to give the user variable striker bar velocities

- Lubricant not needed for general testing (high viscosity deemed detrimental to velocity leading to increased frictional losses due to low weight of bar)

Overall Spent Including R&D

Item	Cost/Unit	Units	Total Cost
3/16" Plexiglass	$9.98	2	$19.96
Manufacturing	$1.75/min	1	$53.40
Springs	$4.11-$12.53	13	$107.66
Stock 6061 2.5x12" 0.5" thick	$12.79-$18.81	2	$31.61
Leveling Mount	$6.78	4	$27.12
Bubble Levels	$5.55-$5.99	2	$11.54
Super Lube O-Ring	$12.28	1	$12.28
Strain Gauges	$8.71	1	$8.71
Shim Stock	$20.89	1	$20.89
Breadboards/Wiring	$14.97	1	$14.97
			$308.14

Estimated Cost Per Unit For Mass Production
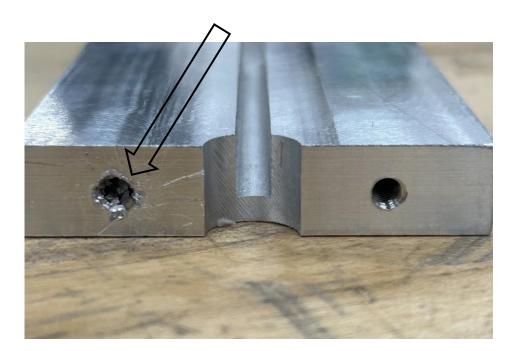
Item	Cost/Unit	Units	Total Cost
3/16" Plexiglass	$9.98/12	1	$0.84
Stock 6061 2.5x12" 0.5" thick	$12.79	1	$12.79
Leveling Mount	$6.78	4	$27.12
Springs	$18.96/12	10	$15.80
Bubble Levels	$5.55/5	1	$1.11
Strain Gauges	$26.13/30	3	$2.62
Shim Stock	$20.89/4	1	$5.23
Breadboards/Wiring	$14.97/4	1	$3.75
Laser Cutting Manufacturing Cost	$106.80/12	1	$8.90
Machining Manufacturing Cost	$725.62/12 + $180/12	1	$75.47
3D Printing Manufacturing Cost	$16.67	1	$16.67
			$170.30

Current Obstacles

- Machined millipede bar base plate does not meet KineticKraft standards
  - Critical surface finish does not meet requirement
  - Threaded holes were not completed, tap broken inside base plate

Next Steps

- Receive manufactured parts

- Assemble functional prototype

- Iterate & Test with functional prototype

- Present to market

Why Us?

- Most cost-effective solution

- Easiest to mass produce and bring to market
    - Easily Scalable
    - 2D Millipede Bar Design
    - Quick Assembly Time