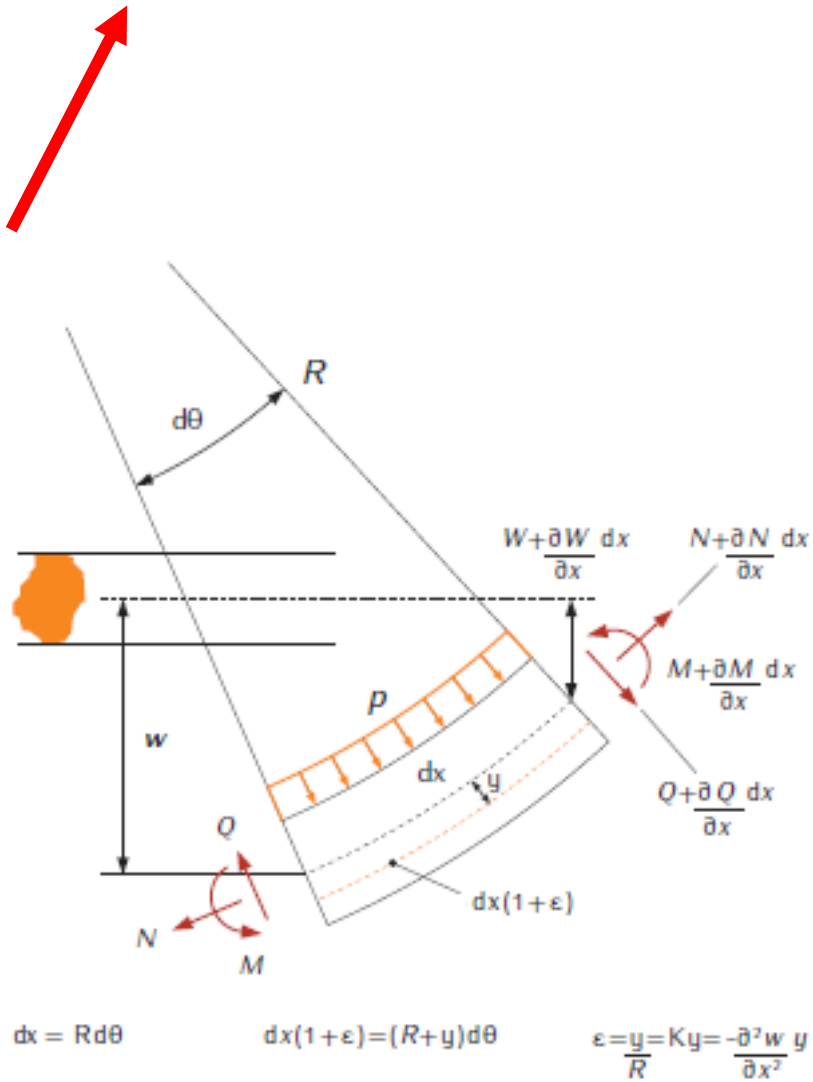


An overview of an integrative approach to building knowledge in the area of impact engineering.

# Modelagem: vibração de vigas [livre + peq. desloc.]: equilíbrio e cinemática



$$\kappa = -\frac{\partial^2 w}{\partial x^2}$$

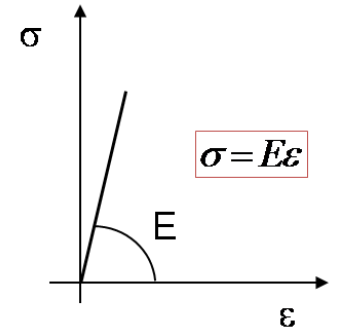
cinemática

$$\frac{\partial^2 M}{\partial x^2} + \frac{\partial}{\partial x} \left( N \frac{\partial w}{\partial x} \right) = -p + m \frac{\partial^2 w}{\partial t^2}$$

equilíbrio

$$M = EI\kappa$$

Material elást. linear



Material elást. linear

$$\frac{\partial^2 w(x,t)}{\partial t^2} + \frac{EI}{m} \frac{\partial^4 w(x,t)}{\partial x^4} = 0$$

# Vibração de viga engastada: condições de contorno

- Condições de contorno:

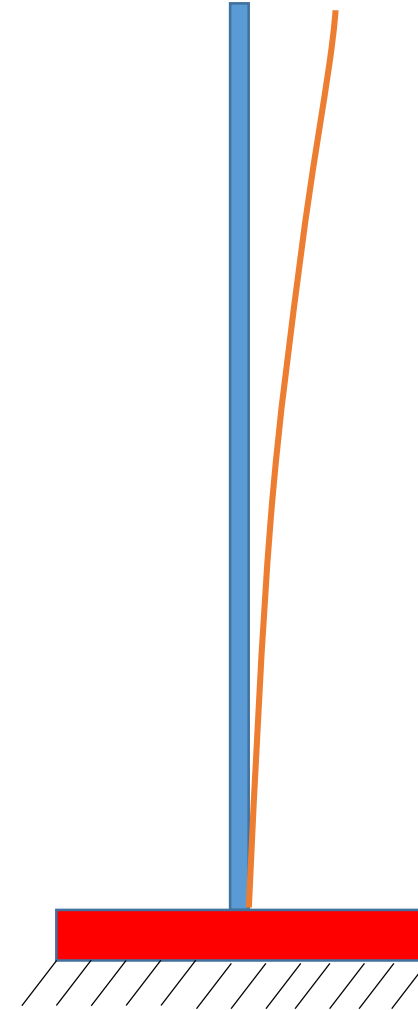
$$M(L) = Q(L) = 0$$

$$w(0) = w'(0) = 0$$

$$1 + \cos(\lambda) \cosh(\lambda) = 0$$

$$\omega_i = 2\pi \left( \frac{\lambda_i}{L} \right)^2 \sqrt{\frac{EI}{m}} \quad \lambda_i = \beta_i L$$

$$\phi_i(x) = \cos \beta_i x - \cosh \beta_i x + \frac{\cos \beta_i L + \cosh \beta_i L}{\sin \beta_i L + \sinh \beta_i L} (\sinh \beta_i x - \sin \beta_i x)$$



# Análise: Adicionando massa no extremo livre, $G$

$$w(0, t) = 0$$

$$w'(0, t) = 0$$

$$w''(L, t) = 0$$

$$Ew'''(L, t) = G\ddot{w}(L, t)$$

$$\underbrace{\begin{bmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ -\text{sen } \lambda & -\text{cos } \lambda & \text{senh } \lambda & \text{cosh } \lambda \\ \mu\lambda \cdot \text{sen } \lambda - \text{cos } \lambda & \mu\lambda \cdot \text{cos } \lambda + \text{sen } \lambda & \mu\lambda \cdot \text{senh } \lambda + \text{cosh } \lambda & \mu\lambda \cdot \text{cosh } \lambda + \text{senh } \lambda \end{bmatrix}}_{=A(\lambda)} * \begin{Bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

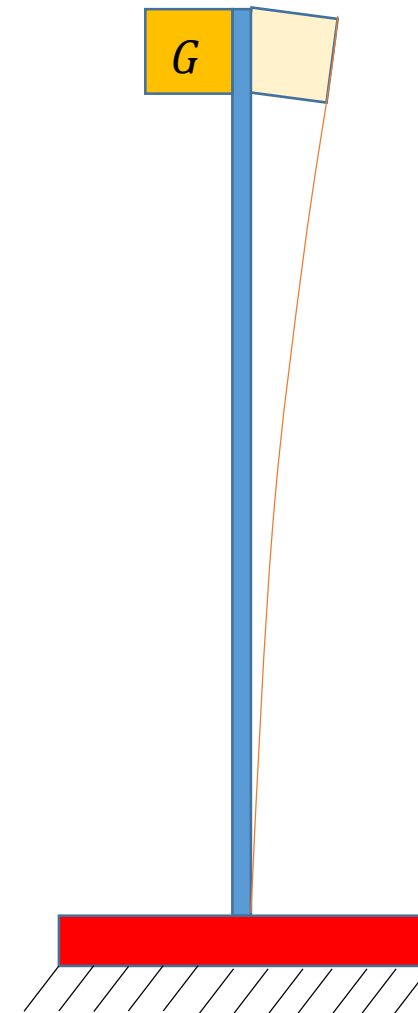
$$\det[A(\lambda)] = 0$$

$$\mu = (G / mL)$$

$$\omega_i^2 = \left( \frac{\lambda_i}{L} \right)^4 (EI / m)$$

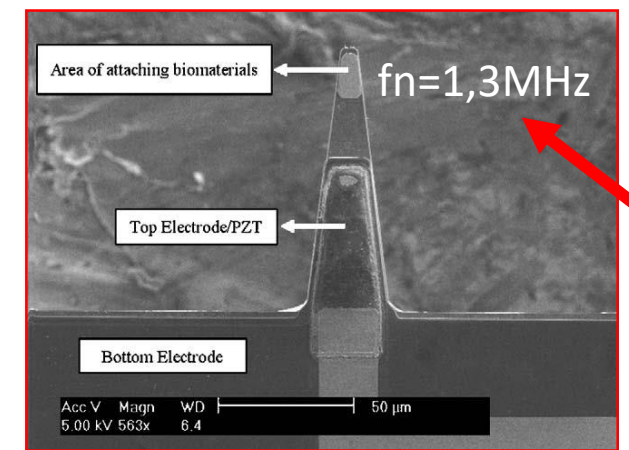
$$\xi = \frac{x}{L}$$

$$\phi_i(\xi) = (\text{sen } \xi \cdot \lambda_i - \text{senh } \xi \cdot \lambda_i) - \frac{\text{sen } \lambda_i + \text{senh } \lambda_i}{\text{cos } \lambda_i + \text{cosh } \lambda_i} (\text{cos } \xi \cdot \lambda_i - \text{cosh } \xi \cdot \lambda_i)$$





# SÍNTESE INTERDISCIPLINAR: nano-balança



- Viga opera na freqüência natural via circuito oscilador
- Anticorpo anti-insulina é imobilizado no sensor
- Sensor é imerso na solução teste
- Insulina se liga ao anticorpo aumentando massa
- Insulina é detectada por um contador de freqüência.
- **$\Delta f = 217 \text{ Hz}$ ,  $\Delta m = 0,45821 \text{ E-}15 \text{ g}$**
- contra  $0,595 \text{ E-}15 \text{ g}$  experimental

Dimensões típicas:

$H = 0,2 - 1 \mu\text{m}$

$B = 20 - 100 \mu\text{m}$

$L = 100 - 500 \mu\text{m}$

# Interdisciplinar: modelagem e análise do coração humano: mec. + elétr. + fluidos

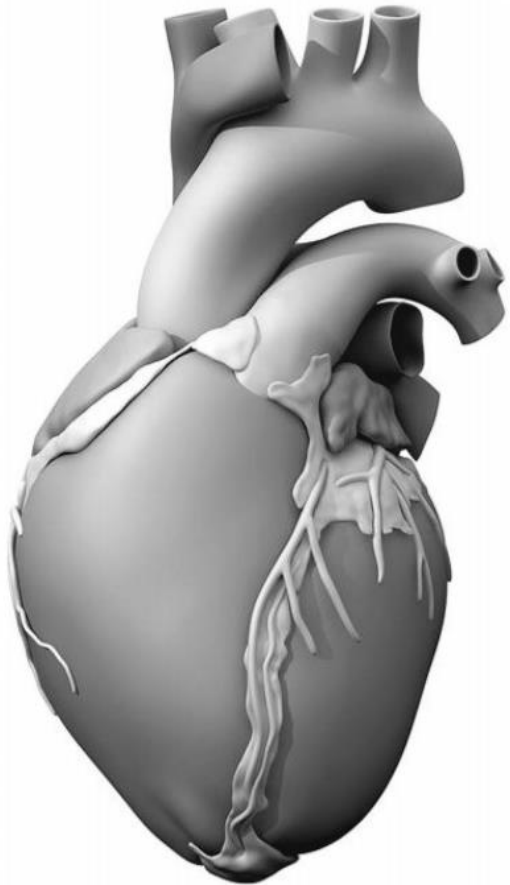


FIGURE 1. Solid model of the human heart used as the basis for our improved model. It was created from computed tomography and magnetic resonance imaging; adapted with permission from (Zygo Media Group and Inc., 2014).

Cardiovascular Engineering and Technology (© 2015)  
DOI: 10.1007/s12239-015-0216-z



Human Cardiac Function Simulator for the Optimal Design of a Novel Annuloplasty Ring with a Sub-valvular Element for Correction of Ischemic Mitral Regurgitation

BRIAN BAILLARGEON,<sup>1</sup> IVAN COSTA,<sup>2</sup> JOSEPH R. LEACH,<sup>3</sup> LIK CHUAN LEE,<sup>4</sup> MARTIN GENET,<sup>5,6</sup>  
ARNAUD TOUTAIN,<sup>6</sup> JONATHAN F. WENK,<sup>7</sup> MANUEL K. RAUSCH,<sup>8</sup> NUNO REBELO,<sup>1</sup>  
GABRIEL ACEVEDO-BOLTON,<sup>3,9</sup> ELLEN KUHL,<sup>9</sup> JOSE L. NAVIA,<sup>7</sup> and JULIUS M. GUCCIONE,<sup>6,10</sup>

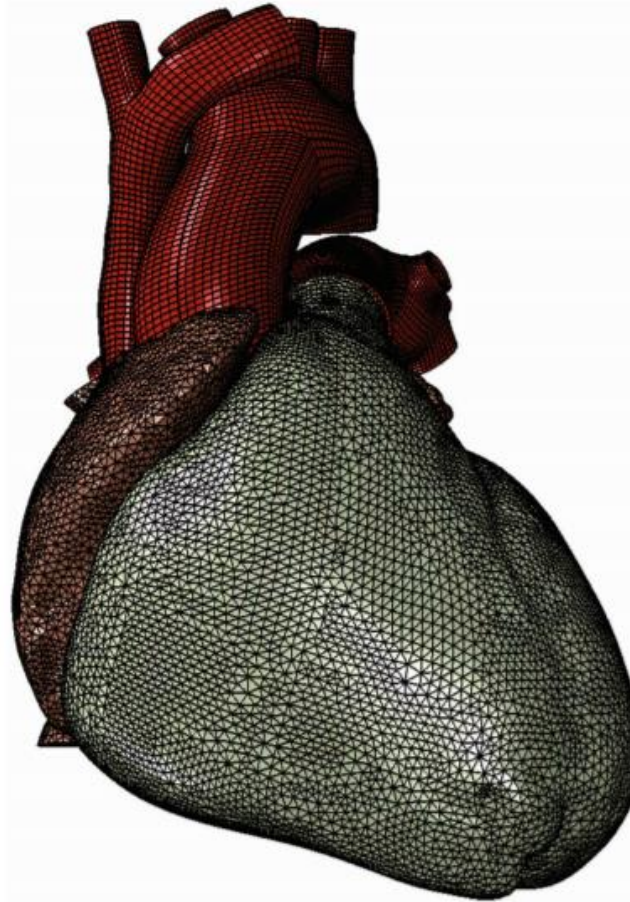
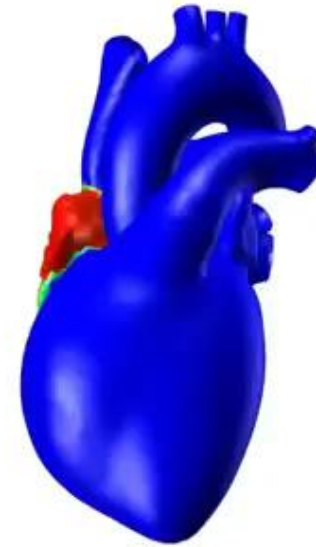
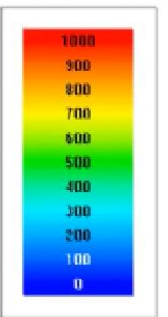
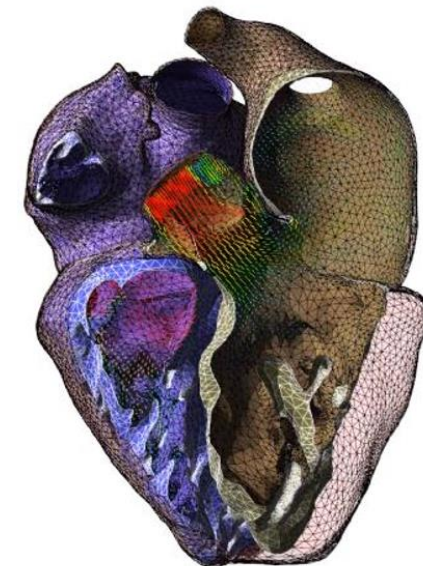


FIGURE 4. Mechanical finite element model of the human heart discretized with 449,560 linear tetrahedral elements, 12,915 linear quadrilateral shells, 7577 linear triangular shells, 636 linear truss elements, 16,824 rigid triangular elements, 130,290 nodes, and 443,564 mechanical degrees of freedom.



The  
Living  
Heart  
Project



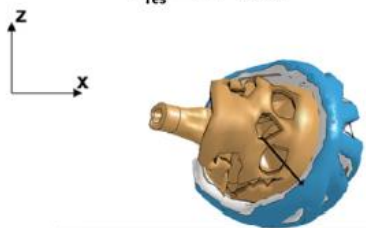
Velocity  
[mm/s]

Uso de capacetes de bicicletas protegem contra:

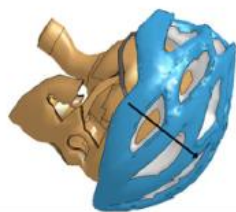
> dano no cérebro (-) e fraturas (+)

> redução de tensões de 80 MPa para 15 MPa

$v_{res} = 5.3 \text{ m/s}$   
 $w_{res} = 4.7 \text{ rad/s}$



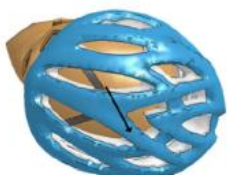
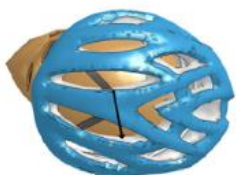
$v_{res} = 7.2 \text{ m/s}$   
 $w_{res} = 1.8 \text{ rad/s}$



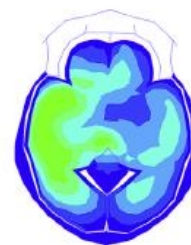
$v_{res} = 4.3 \text{ m/s}$   
 $w_{res} = 2.2 \text{ rad/s}$



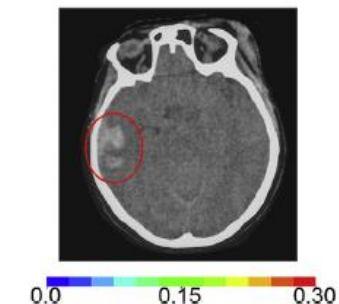
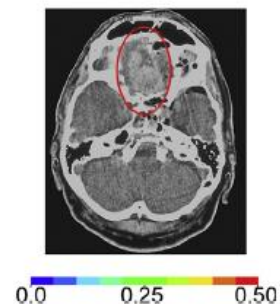
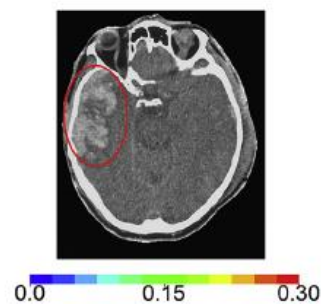
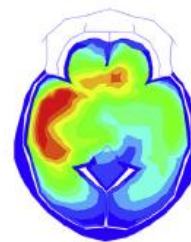
$z$   
 $y$



Helmet



No  
Helmet





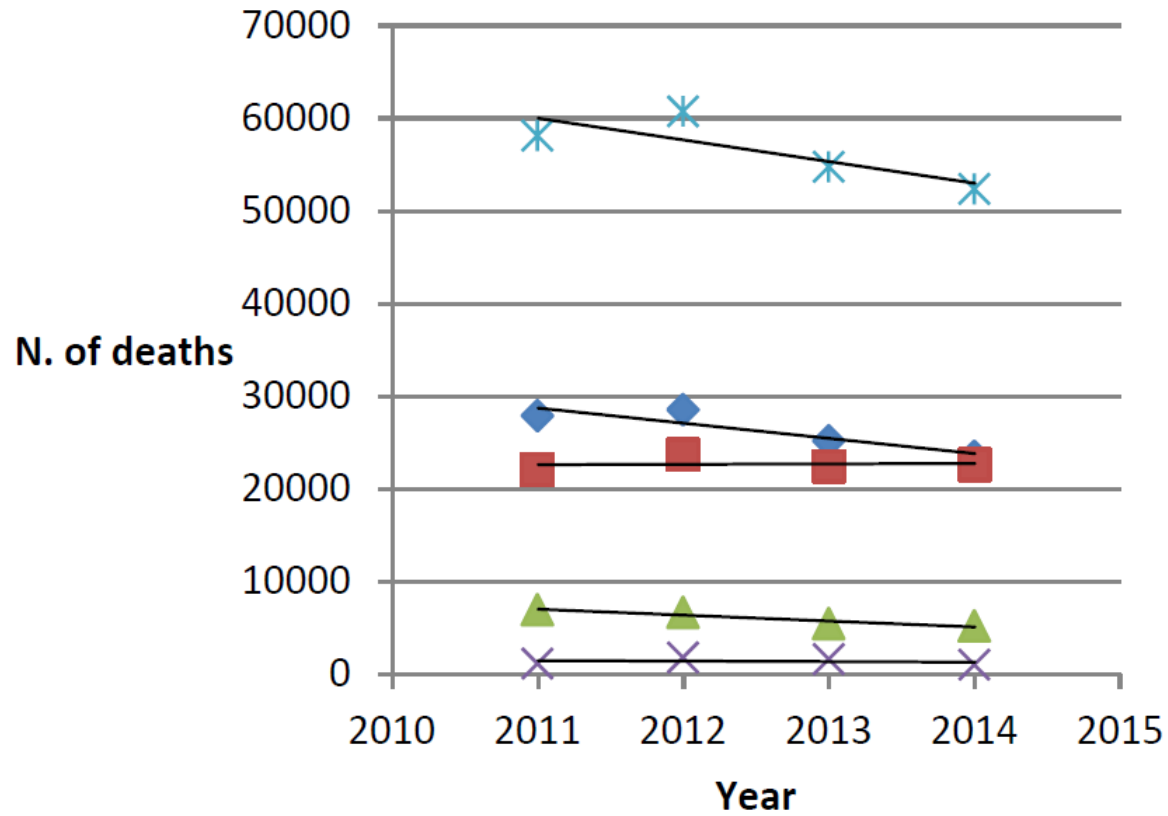
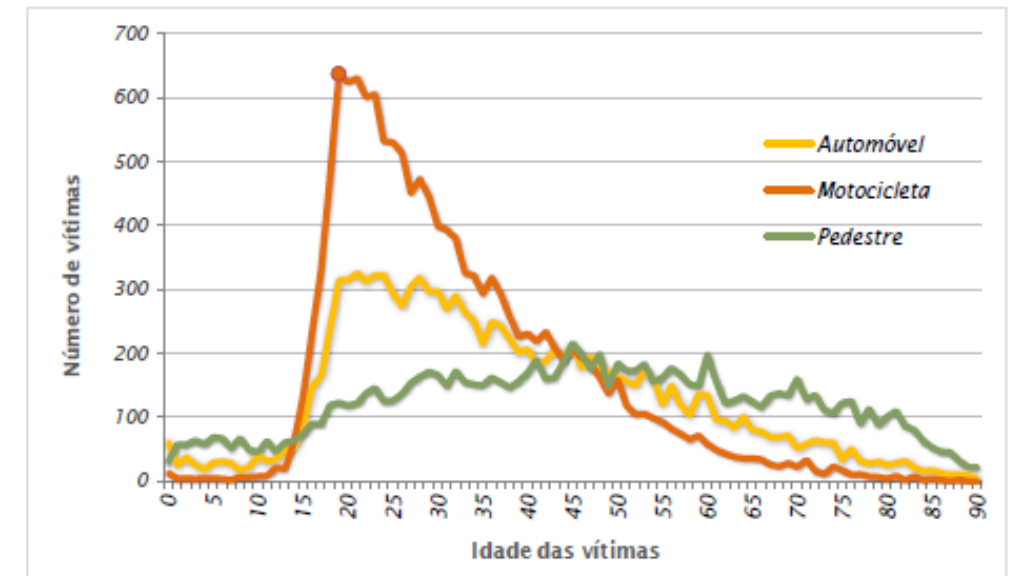
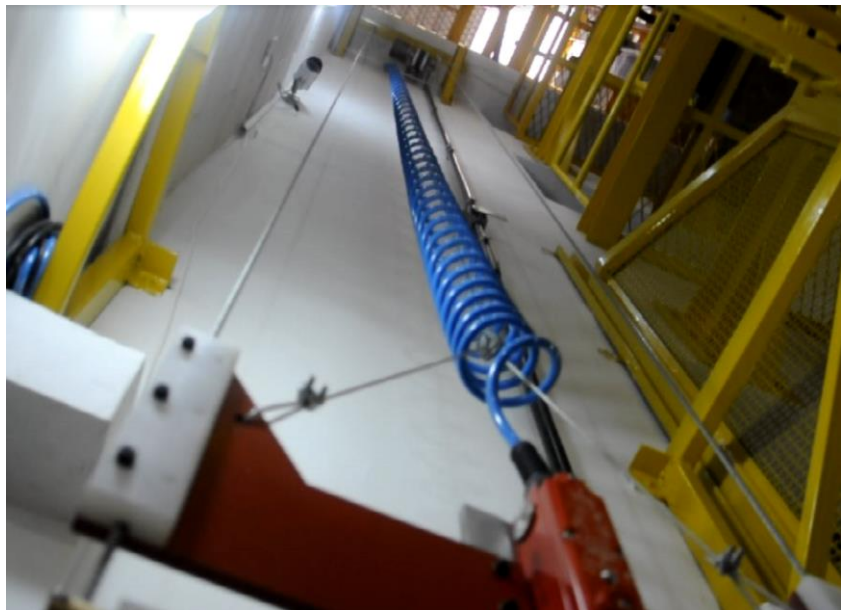


Gráfico 10.1.1. Número de óbitos em acidentes de trânsito por idades simples e categoria 1. Brasil. 2011.



Fonte: SIM/SVS/MS



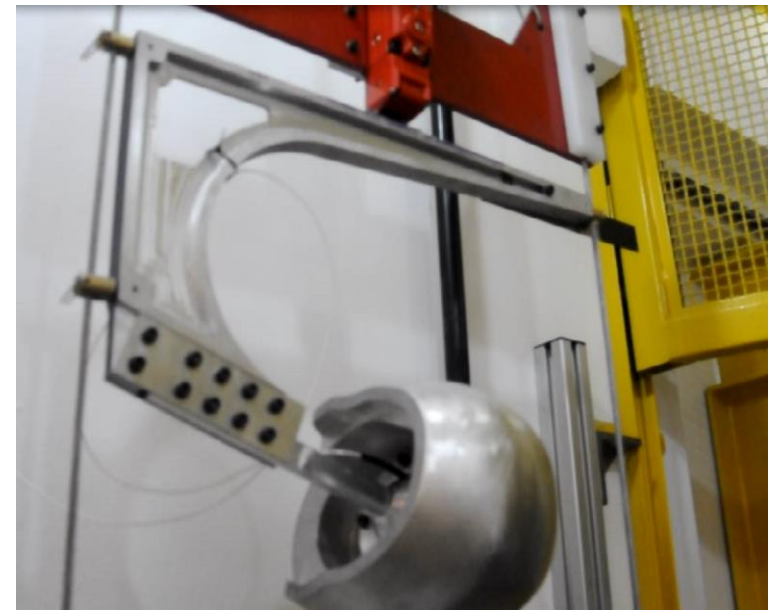


UN  
BRASIL

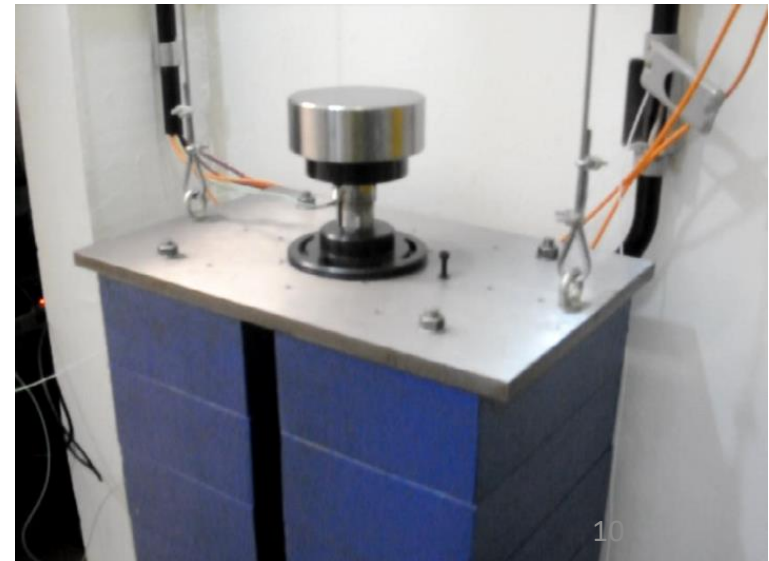
27.0 km/h = 7.5 m/s  
25.2 km/h = 7.0 m/s

$a_{max} = 275 \text{ g}$  e  $HIC < 2400$   
 $a_{max} = 300 \text{ g}$  e  $< 150 \text{ g @ 5 ms}$

Flat + Kerbstone R = 15 mm  
Flat + Hemispherical R = 50 mm

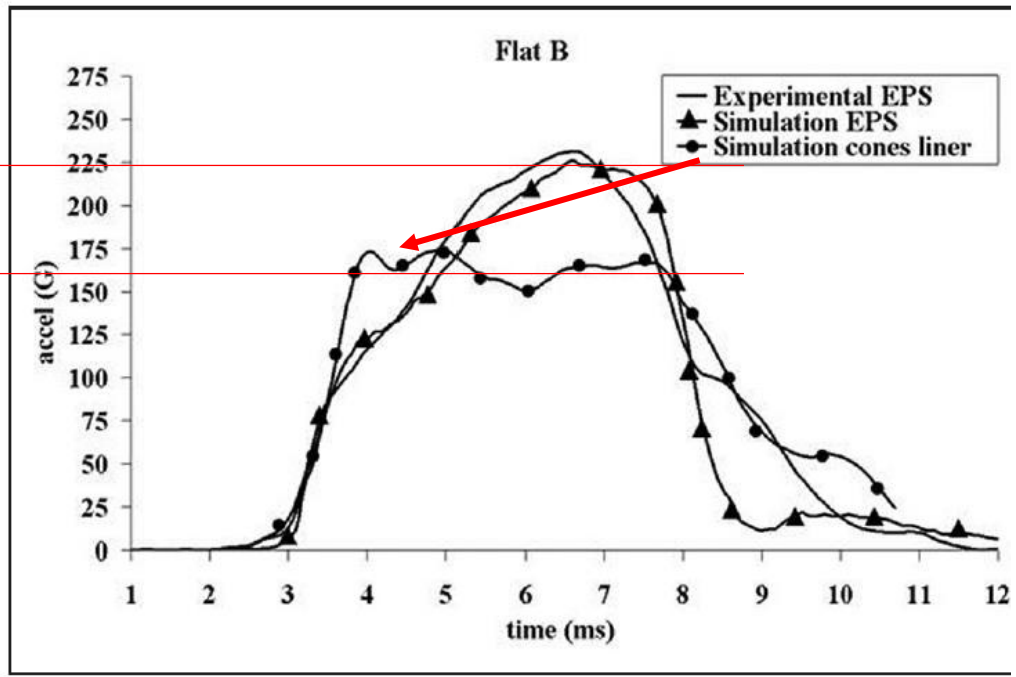
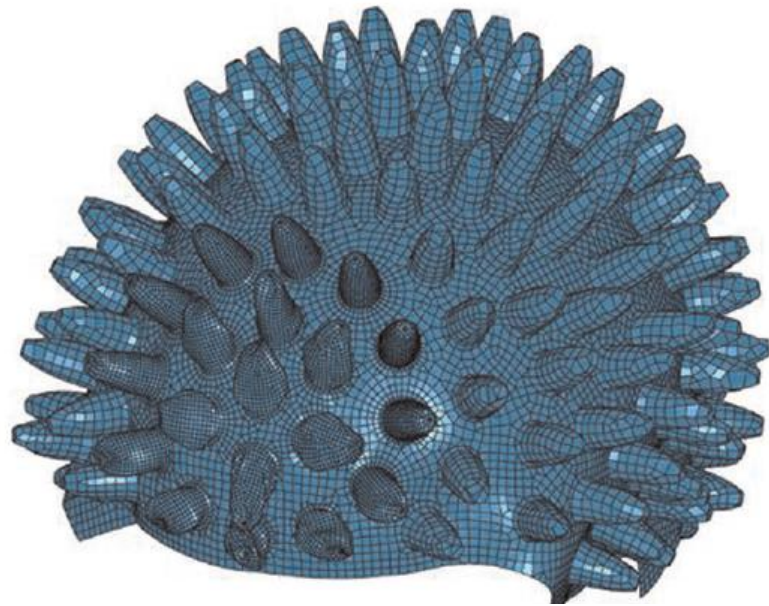


Type	Origin	EXPEC RESULTS
AGV K3	IMP	★★★★★
Shark S700	IMP	★★★★★
LS2 FF358	IMP	★★★★ 4 Stars in EU
Protork Evolution 3G	BR	★★★★
EBF <u>Rox</u>	BR	0
Taurus San Marino	BR	0
EBF E8	BR	0
NORISK FF391	IMP	0
Protork Liberty 4	BR	-
Taurus <u>Zaref</u>	BR	0





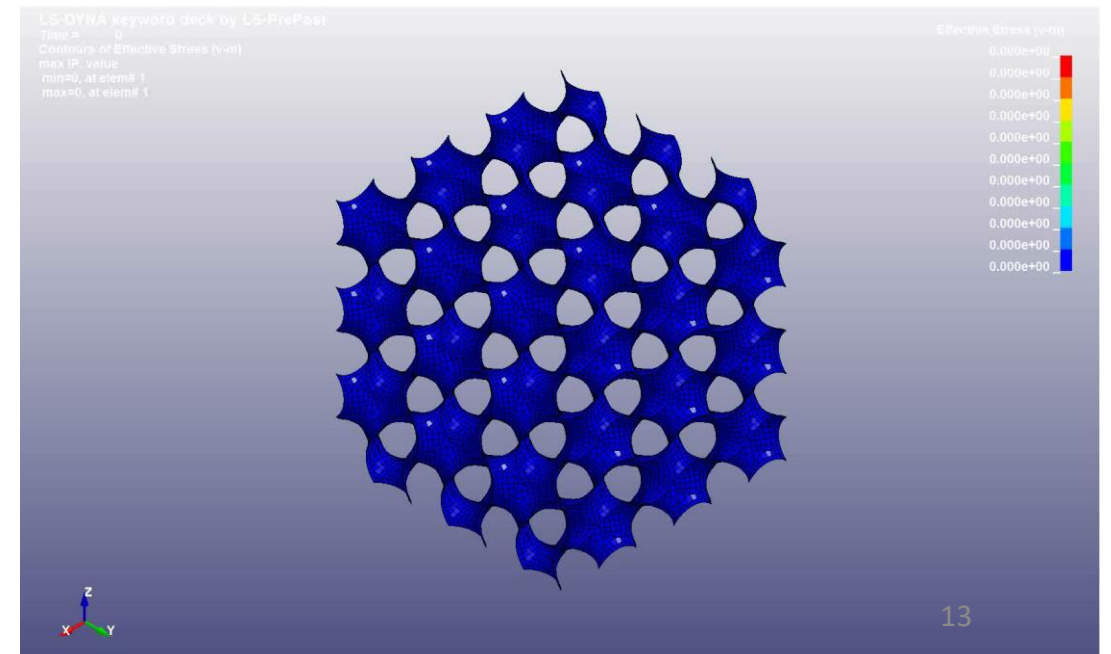
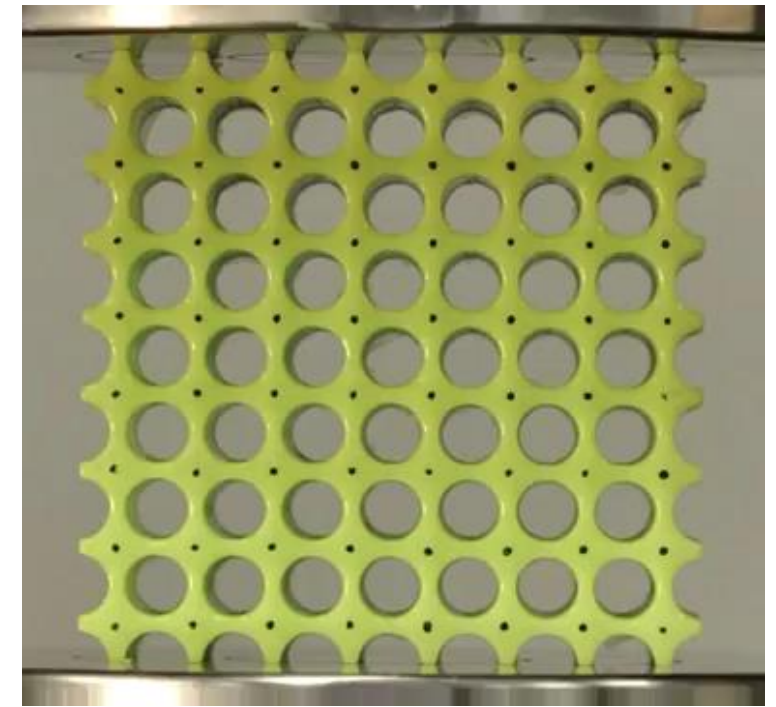
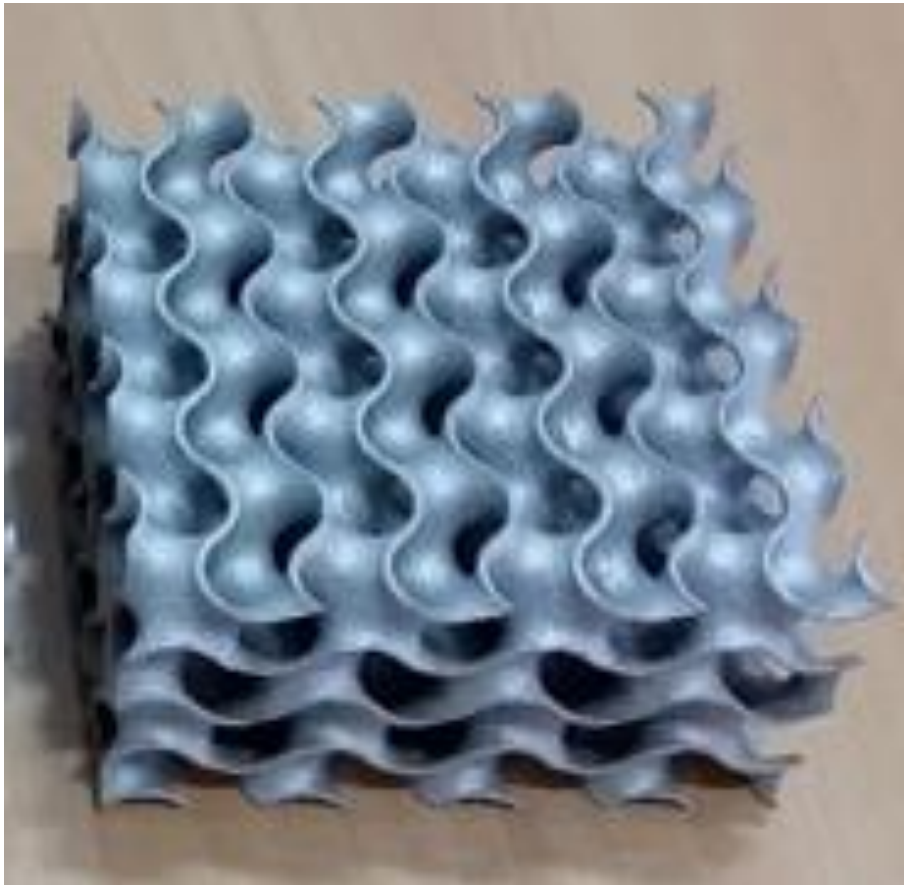
Modelagem  
Análise  
Síntese



**Figure 17.** Comparison between experimental and numerical data for impact at point B. EPS: expanded polystyrene.

# Metamateriais [futuro]

Metamateriais: propriedades macroscópicas vêm + de sua subestrutura e – da composição química



# Trabalho do músculo convertido para salto, com $g$ afetando modelo e protótipo

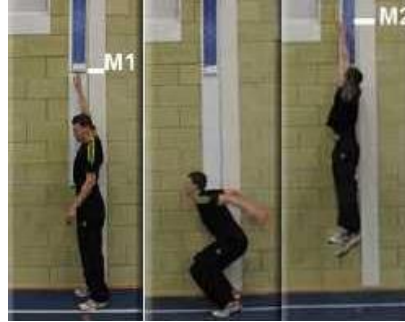
$$E_p = mgh$$

$$W = Fd$$

$$E_p = W$$

$$h = \frac{Fd}{mg}$$

$$h \propto \frac{L^2 L}{L^3} \propto L^0$$



70 kg

70 cm



3 g

59 cm



40 mg

30 cm



0,49 mg

20 cm

Todos os animais, conquanto de mesmo estilo, com suas alavancas na mesma proporção, devem saltar não à mesma posição relativa, mas à mesma posição de fato.

- Altura do salto não depende da massa
- Peso difere por mais de 100 milhões



# Deformação estrutural programada



## GMSIE LAB

**Quasi-Static test: 0.5 mm/min**

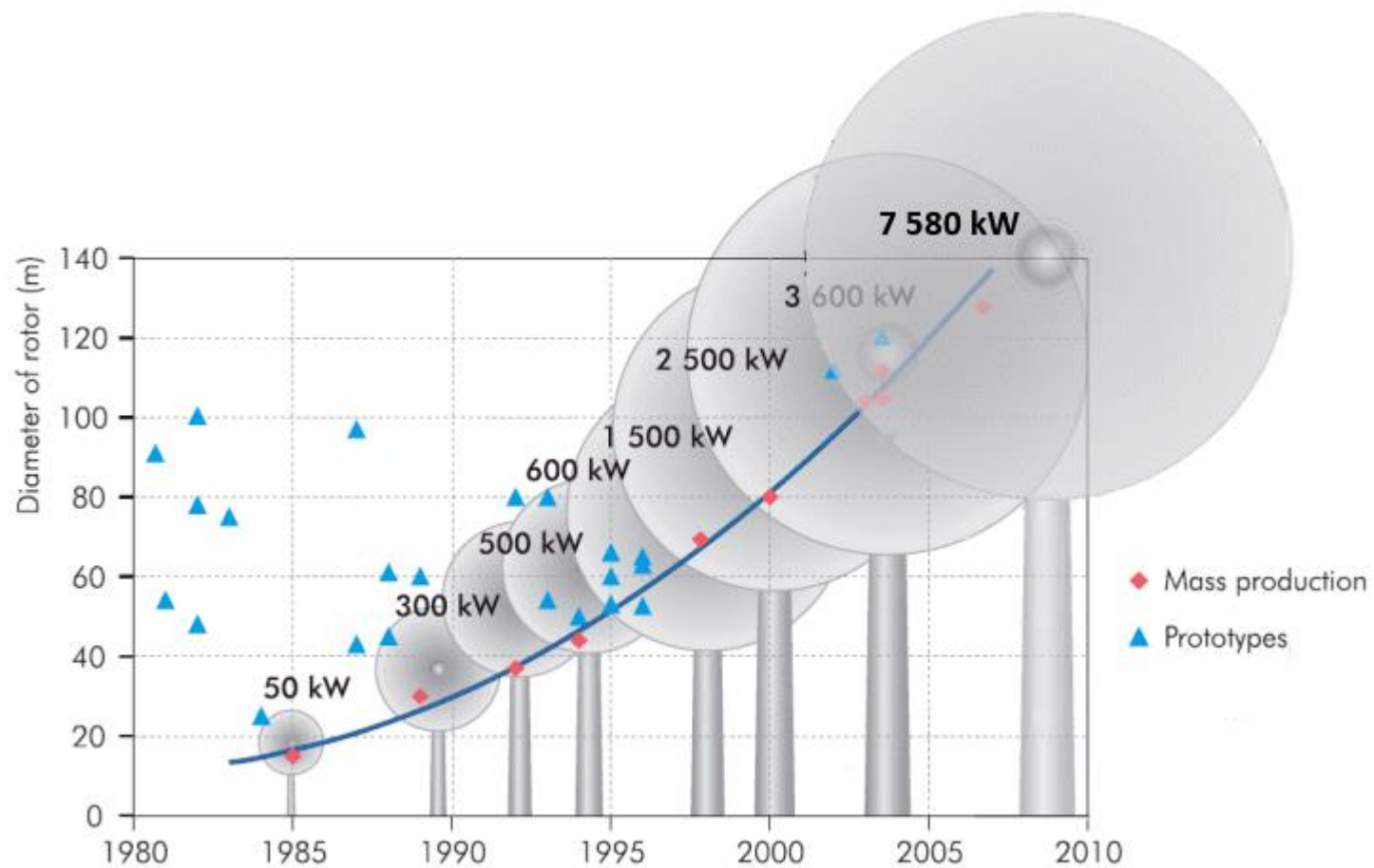
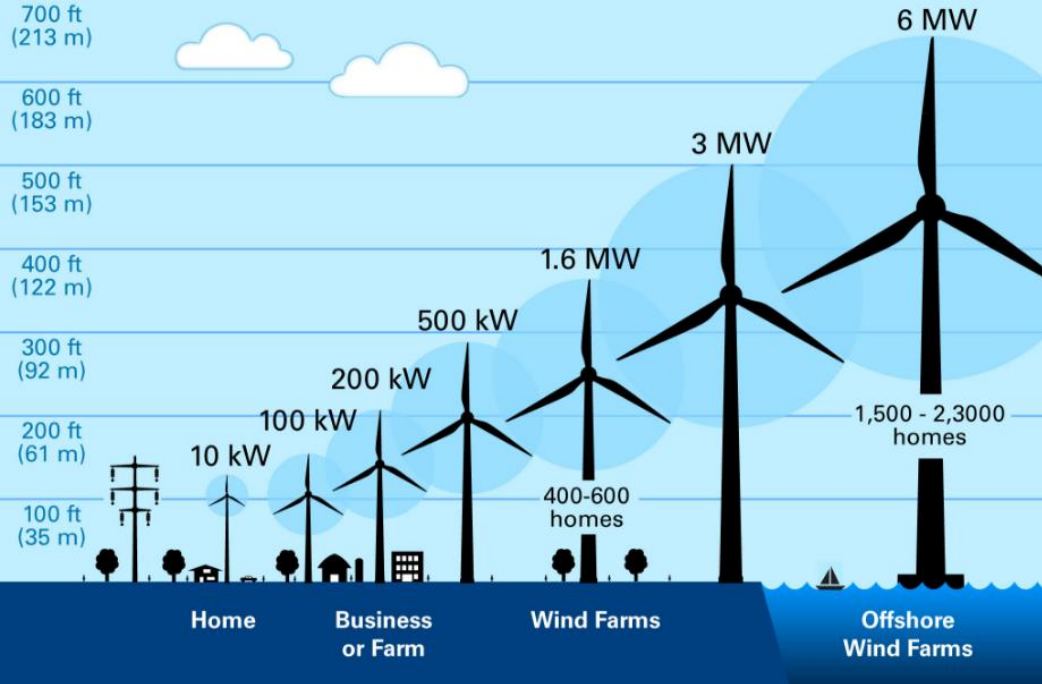
**CarbonFiber Tube**

**Wall Thickness: 2.38 mm**

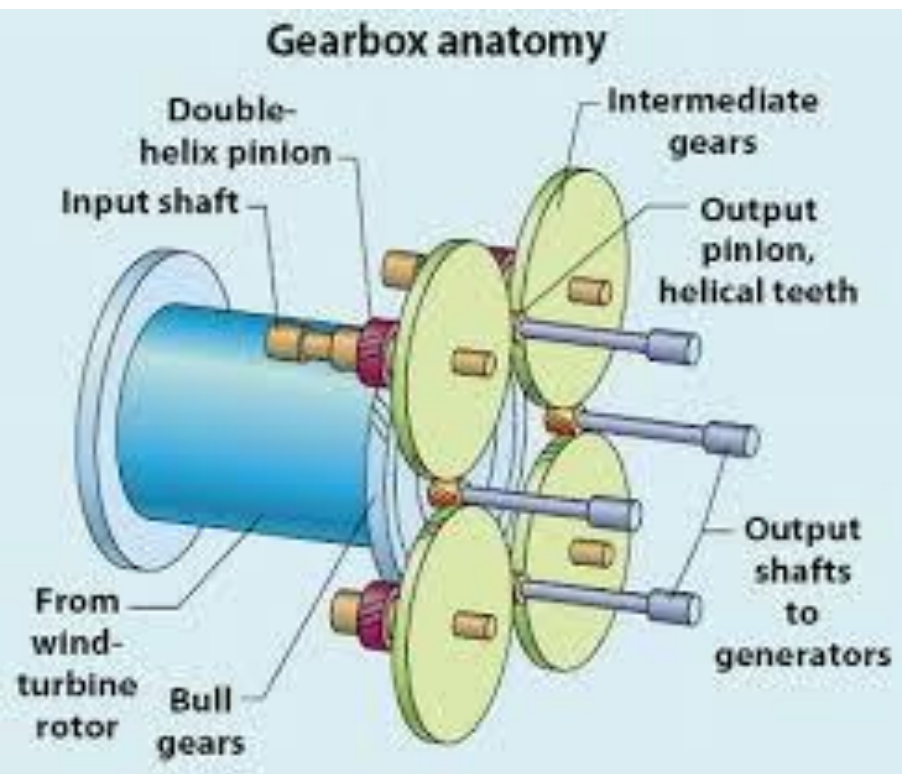
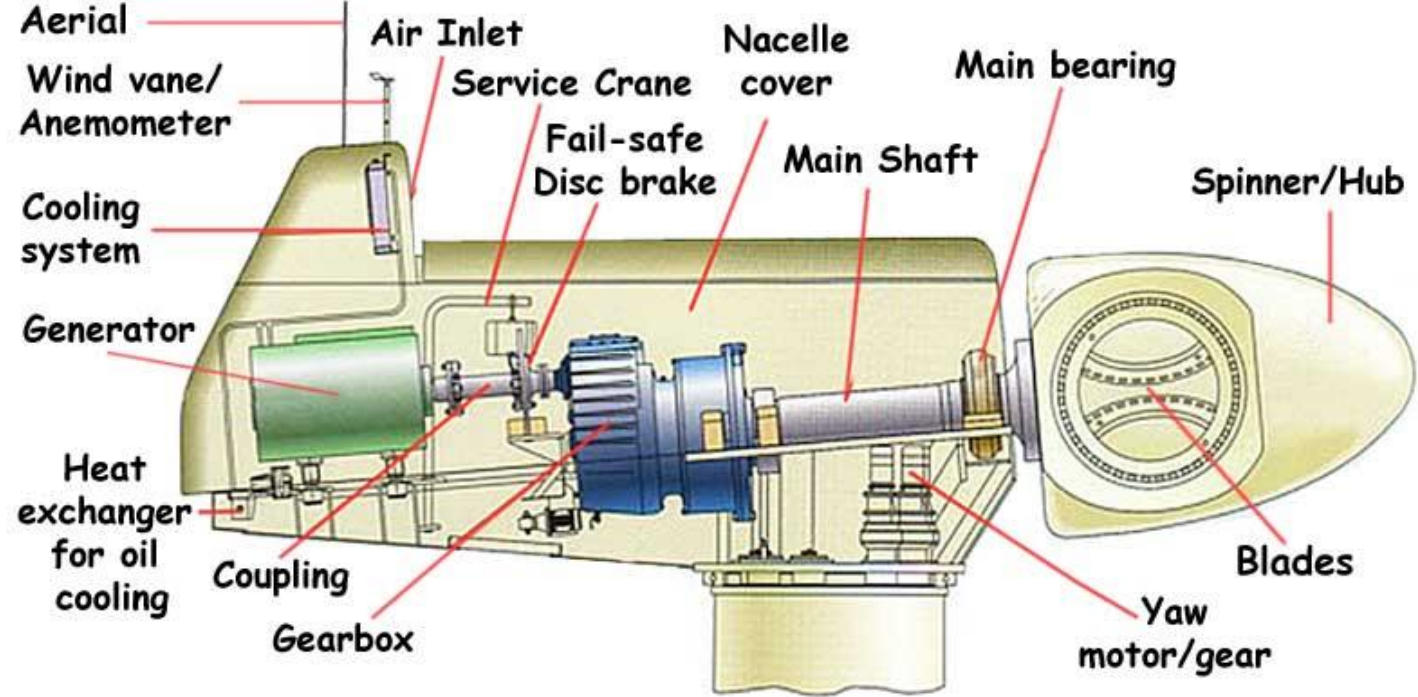
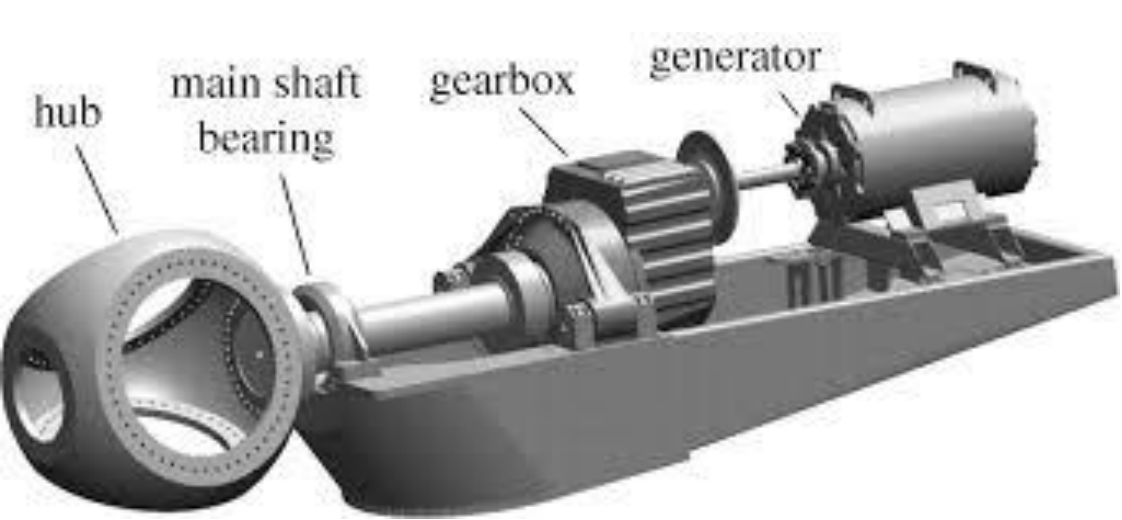
**Staching Sequence: [ $\pm 45/0/\pm 45/0/\pm 45/0/\pm 45$ ]**

**Tube's ends condition: (flat)-(45 degree chamfer)**



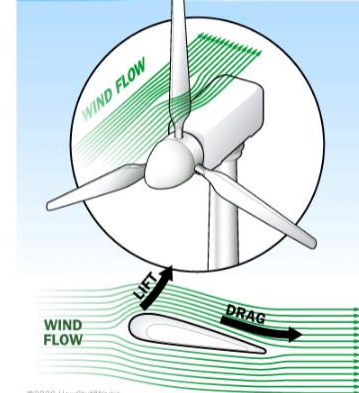


Source: International Energy Agency (IEA)

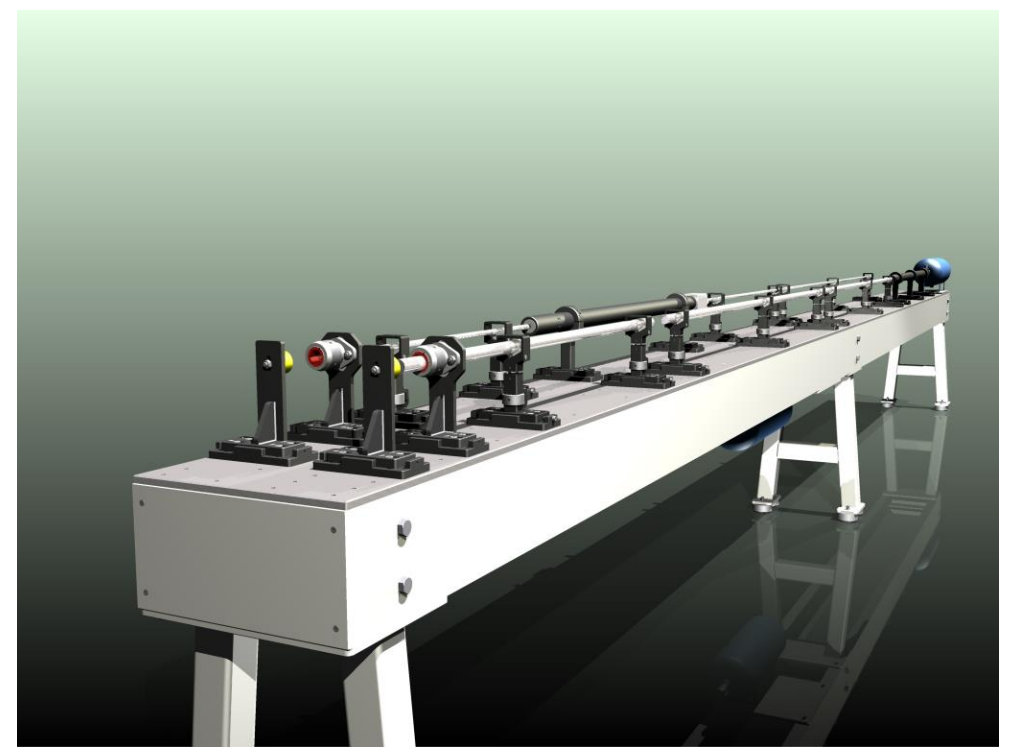
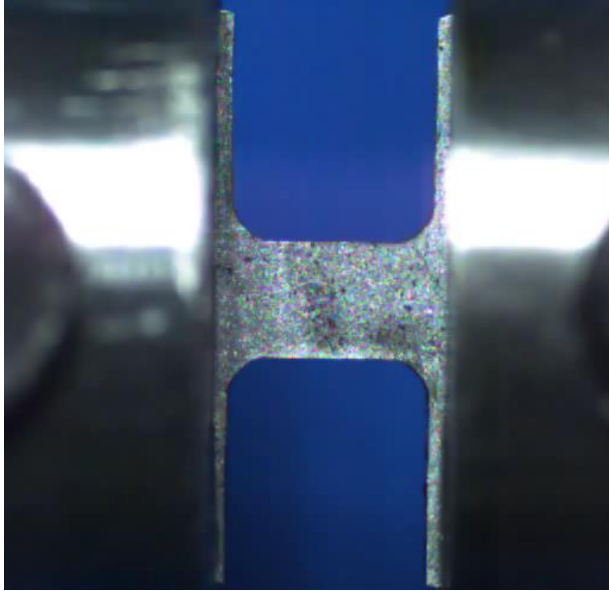


Turbine Aerodynamics

How Wind Power Works Turbine Aerodynamics



# Barra de Hopkinson: síntese como um ato de engenharia



FASTCAM-APX RS 25...

30000 fps

1/30000 sec

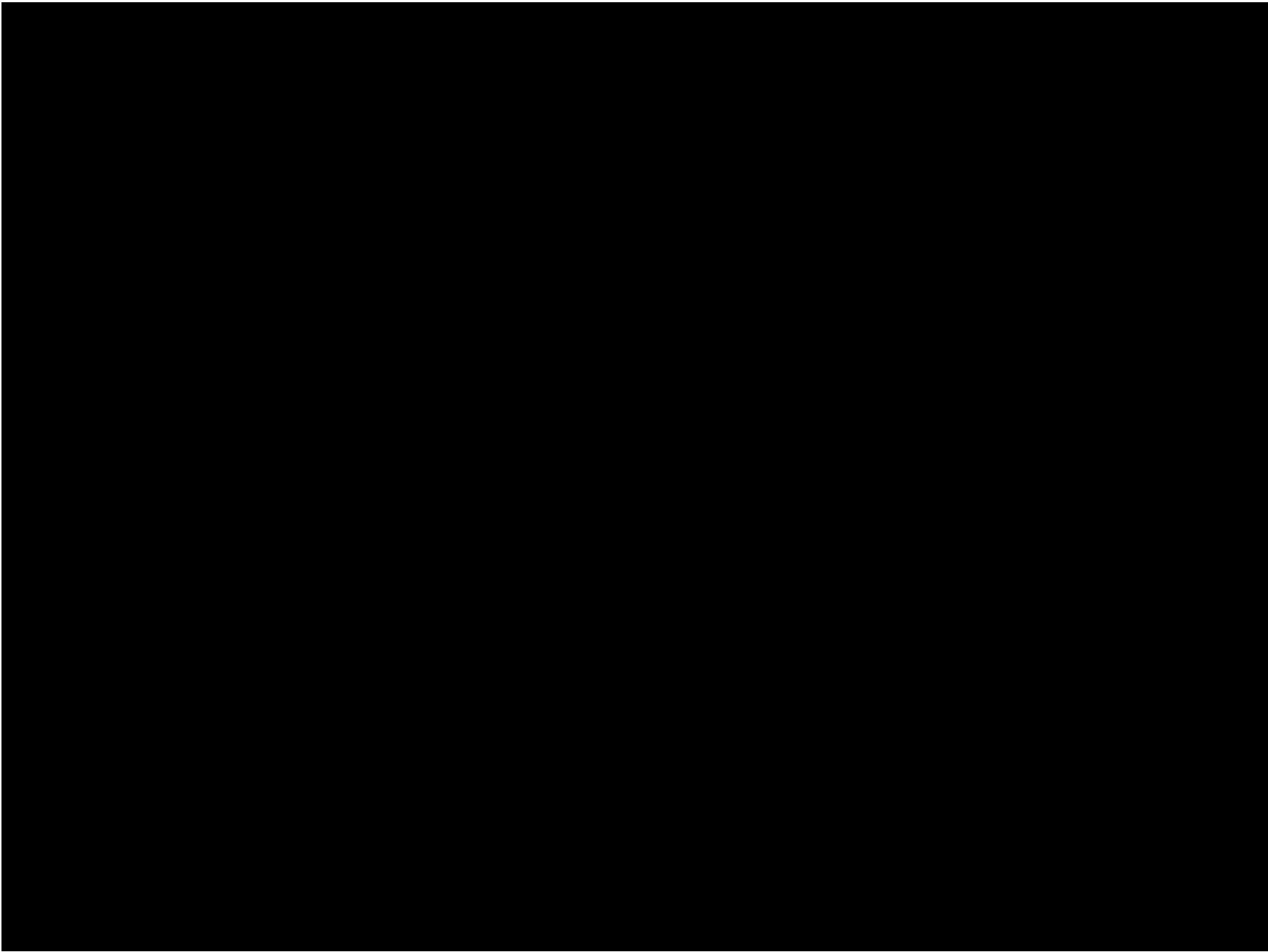
384 x 176

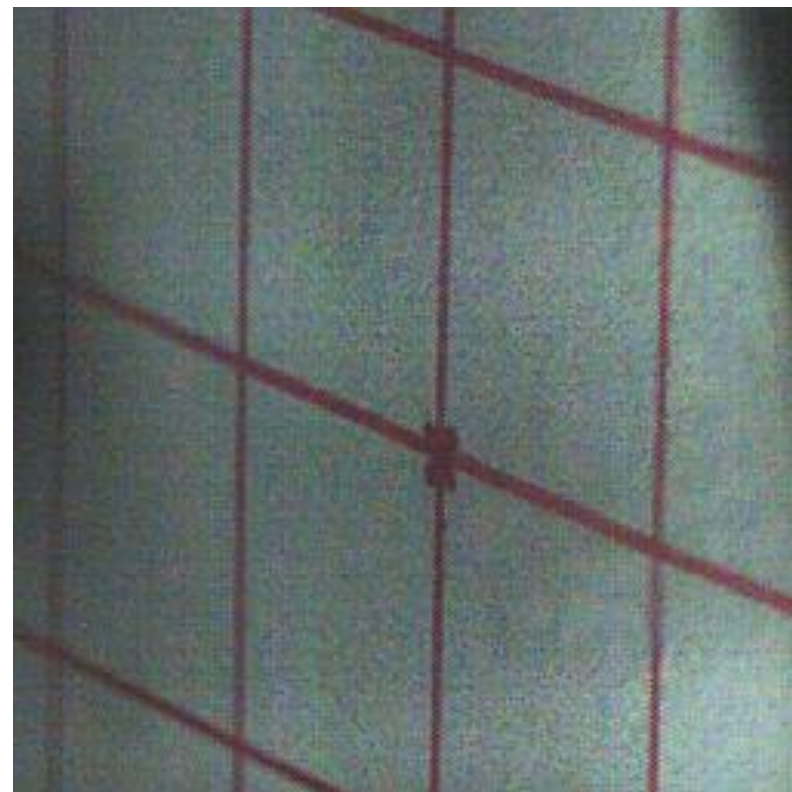
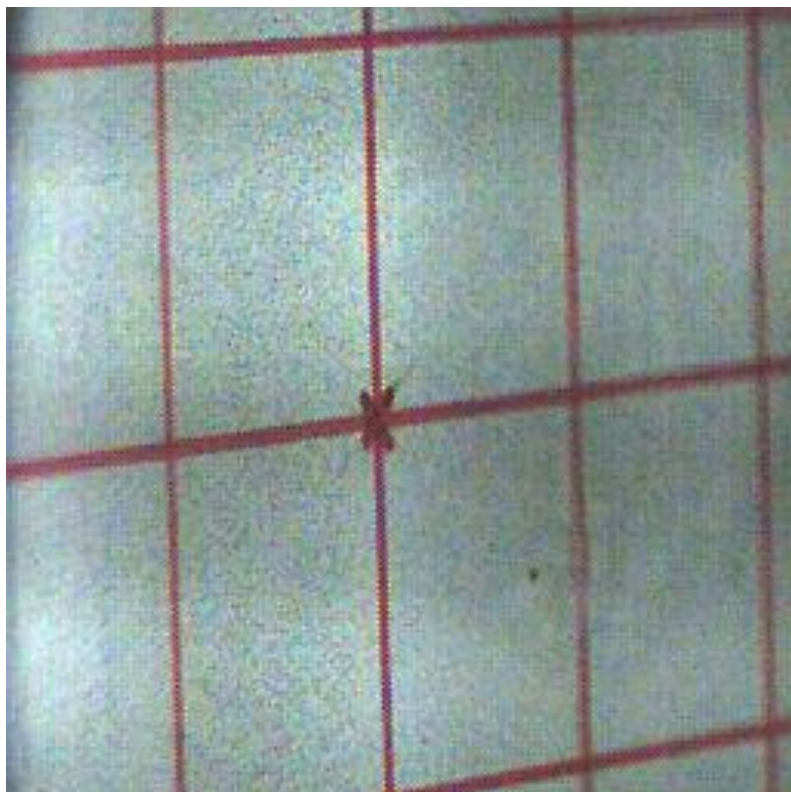
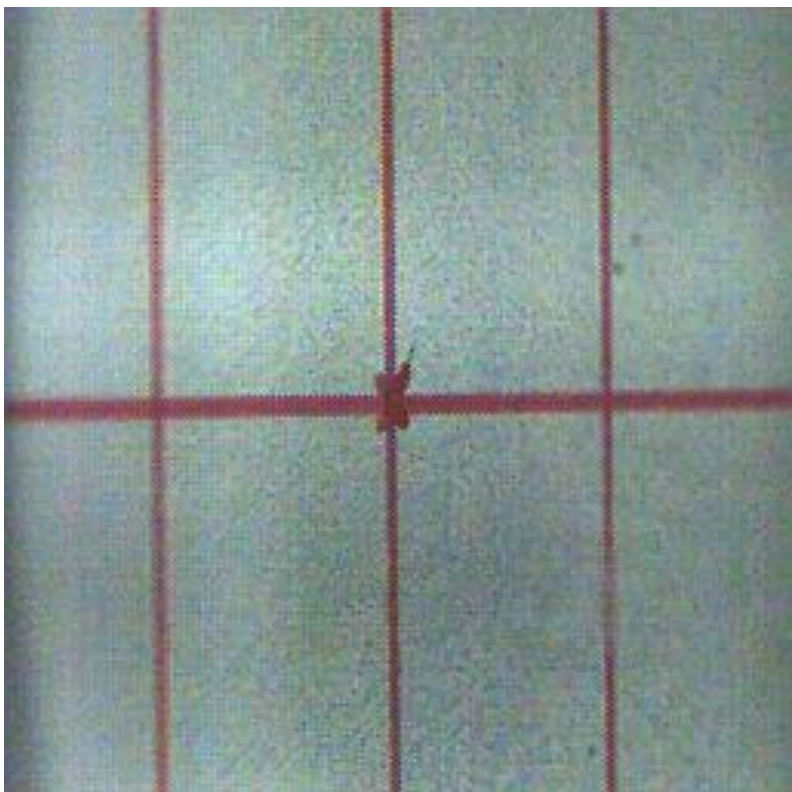
frame : -11600

-00:00:00.386667sec

**Photron**



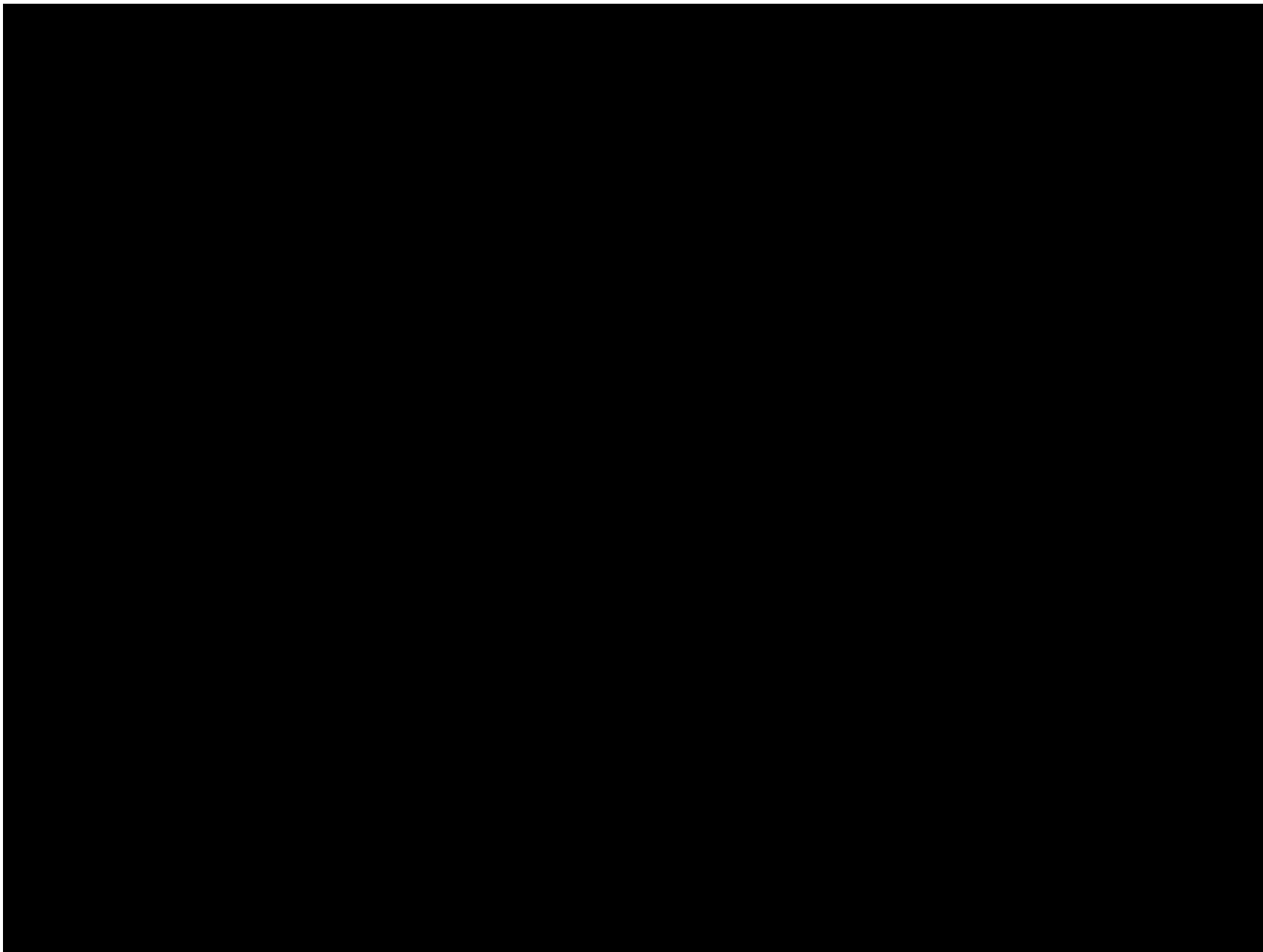




STORY OF THE

NARROWS BRIDE

— 1940



[https://www.youtube.com/watch?v=eAXVa\\_XWZ8](https://www.youtube.com/watch?v=eAXVa_XWZ8)

<https://www.youtube.com/watch?v=gQK21572oSU> London bridge opening

# **The Resonant Bridge**

**by Bob Barrett  
Messiah College  
Box 3041**

**Grantham PA 17027 USA**





[https://www.youtube.com/watch?v=uENITui5\\_jU](https://www.youtube.com/watch?v=uENITui5_jU) water hose

<https://www.youtube.com/watch?v=Q3oItpVa9fs#t=10> cinematics

All of the experiments  
in this video are real.

<https://www.youtube.com/watch?v=vvJAgUBF4w> plate vibration

