Electrothermal Launcher and PDV used for calibration of Polyvinylidene Fluoride (PVDF) pressure gauges

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Outline

- Motivation
- Method
- Results
- Issues
- Conclusions

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Motivation

- High velocity forming: impact pressures upto 1 GPa and strain rates $>10^3\ s^{-1}$
  - increases formability
  - reduces springback
- Direct measurements of impact pressures with high temporal resolution needed
- Presently Manganin (piezoresistive), quartz (piezoelectric) and Lithium Niobate (piezoelectric) gauges are most commonly used for to determine shock pressures

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Motivation

- Characteristics of common gauges
  - Manganin: Good: Used when 5-10% accuracy is acceptable. Bad: Have to be "seasoned" to make reproducible; Passive
  - Quartz: Good: Active; very accurate. Bad: Brittle and suitable only for plane wave measurements
  - Lithium Niobate: Good: Active; high signal to noise ratio. Bad: Brittle; charge output during failure is not well studied; thick gauges are required

Motivation

- Characteristics of PVDF gauges:
  - High molecular weight polymer of monomer (CH_2-CF_2). 50% crystalline and 50% amorphous
  - Good: Active; tough, lightweight, flexible, dimensionally stable; does not age at temperatures below 80°C; high dielectric constant, readily manufactured in sheet form and can be fabricated into complex shapes; cheap (Model LDT1-028K : $4.64 each)
  - Calibration data not readily available…….???

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Method

Force α Charge (Q)

$$\int V(t)\,\mathrm{d}t = R\int I(t)\,\mathrm{d}t = RQ(t)$$

since

$$I = \frac{\mathrm{d}Q}{\mathrm{d}T}.$$

Since

$$Q(t) = \frac{1}{R}\int V(t)\,\mathrm{d}t$$

then

$$\frac{Q}{A} = \frac{1}{RA}\int V(t)\,\mathrm{d}t. \quad \mathbf{= k*P}$$

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Method

- Particle velocity (u_p) = ½ * Impact velocity (u_i) (symmetry)
- Rear surface velocity (u_r) = 2 * Particle Velocity (u_p) <= Impact velocity (u_i)
- $P = \rho * u_s * u_p$
- ρ (PMMA) = 1.18 gm/cm^3
- $u_s = 3.1 + 1.32\ u_p$ km/s (Bakanova)
- $u_s = 3.51 + 1.25\ u_p$ km/s (Hauver)

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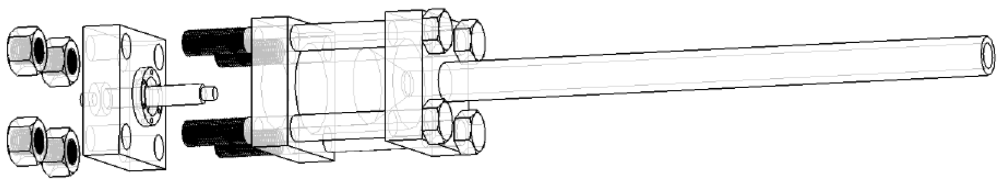
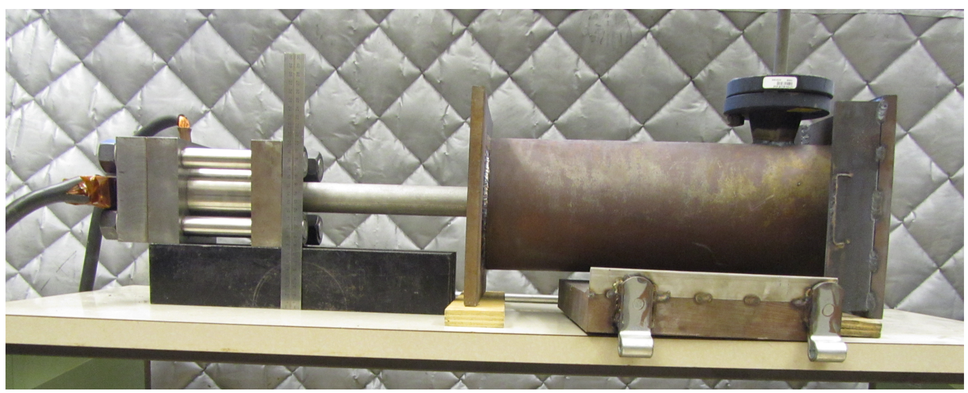
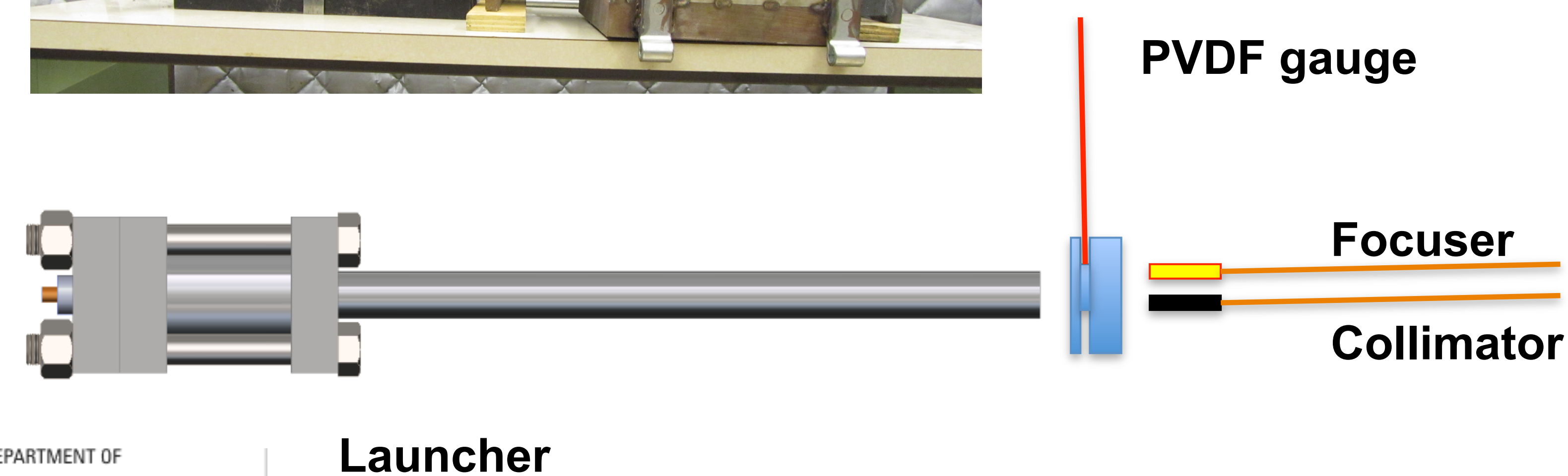
Method







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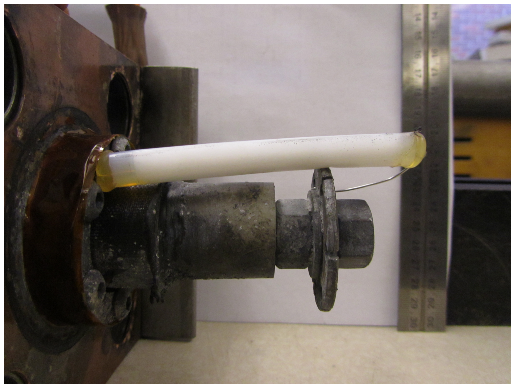
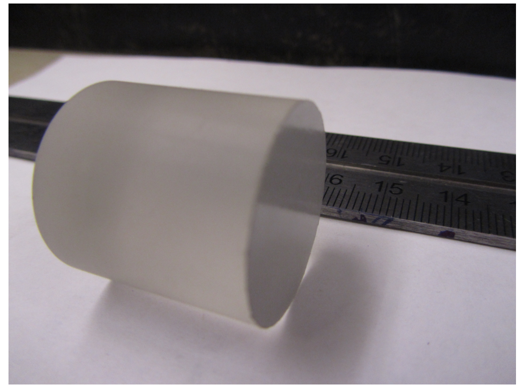
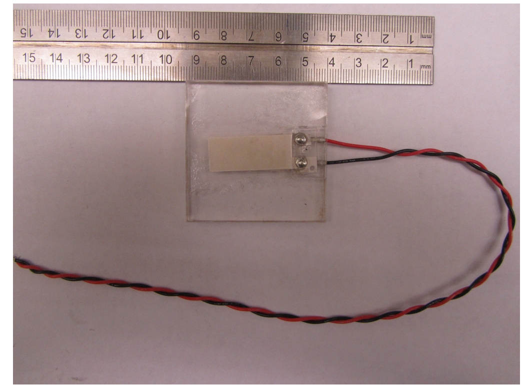
Method



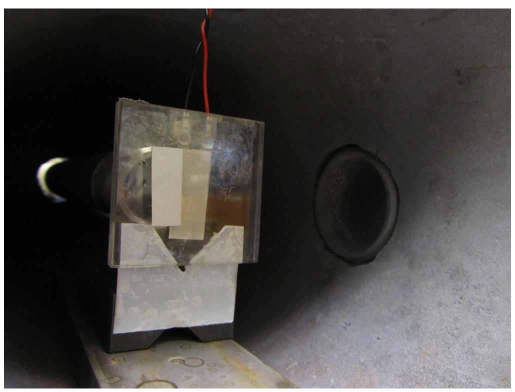
Wire with augment



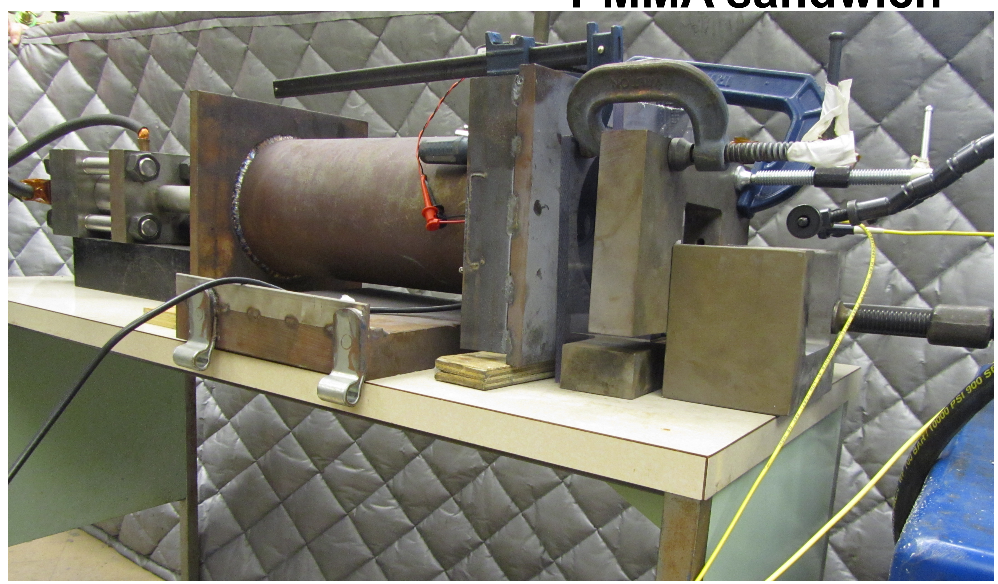
PMMA projectile



PVDF gauge in PMMA sandwich



PVDF gauge on the mount



Electrothermal launch system for PVDF calibration

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Method

- Materials:
  - Target: PMMA sheets with PVDF sandwiched in between. Cyano acrylate glue used to hold the sandwich together
  - Projectile: 25.4 mm and 50.8 mm long and 25.4 mm diameter PMMA
  - Launching material: 0.762 mm diameter aluminum wire; 10 gm of $KClO_3$(oxidizer)+kerosene (fuel)

Results

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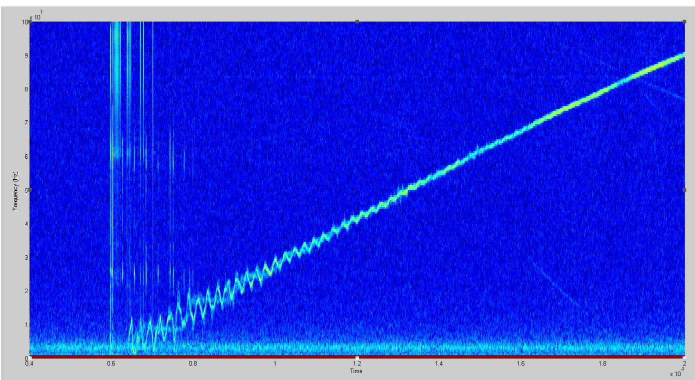
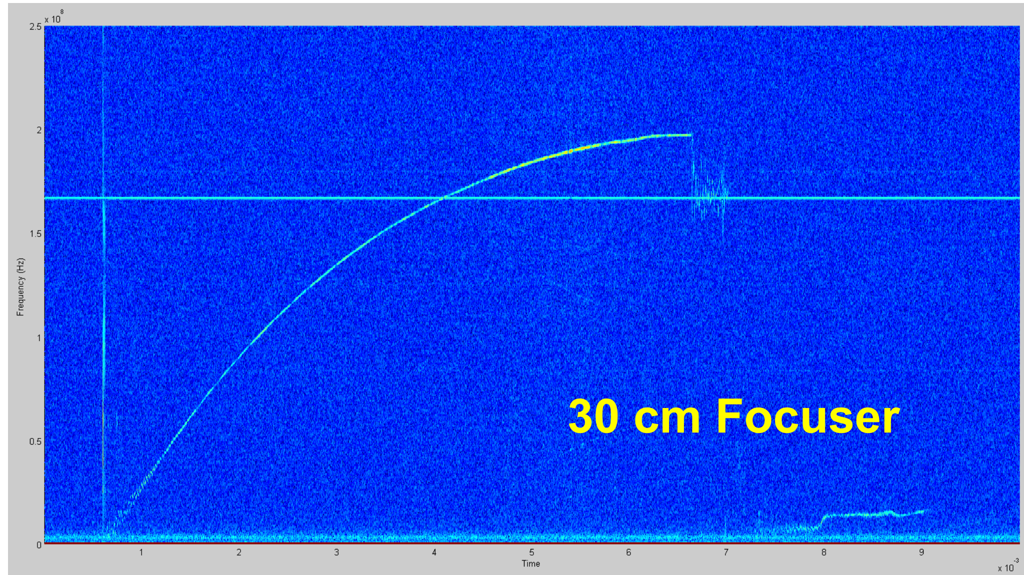
Without augment

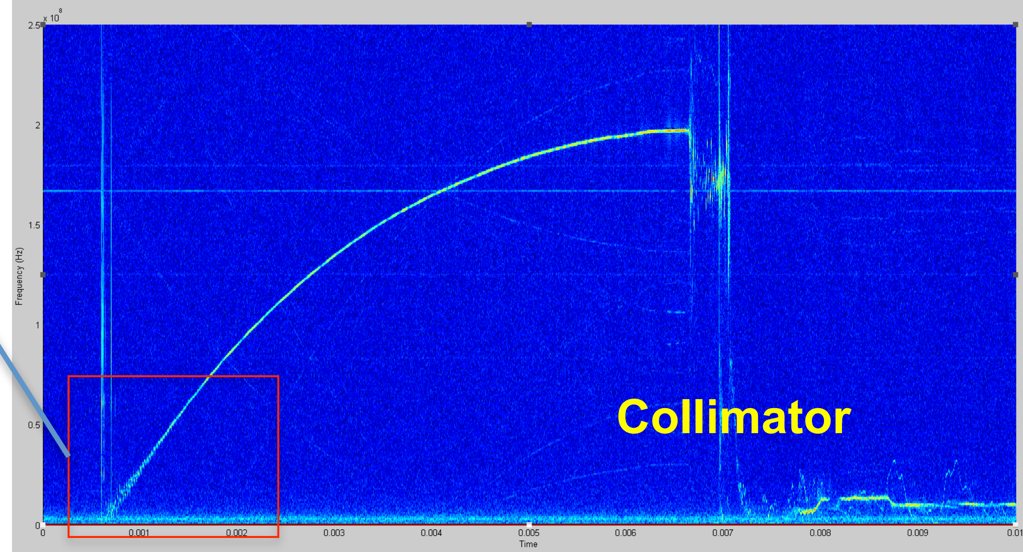
Input energy: 9.6 kJ

Projectile: 50.8 mm long PMMA



Period of wave(T)=0.024 ms
Shock speed=2L/T=4.32 mm/ms





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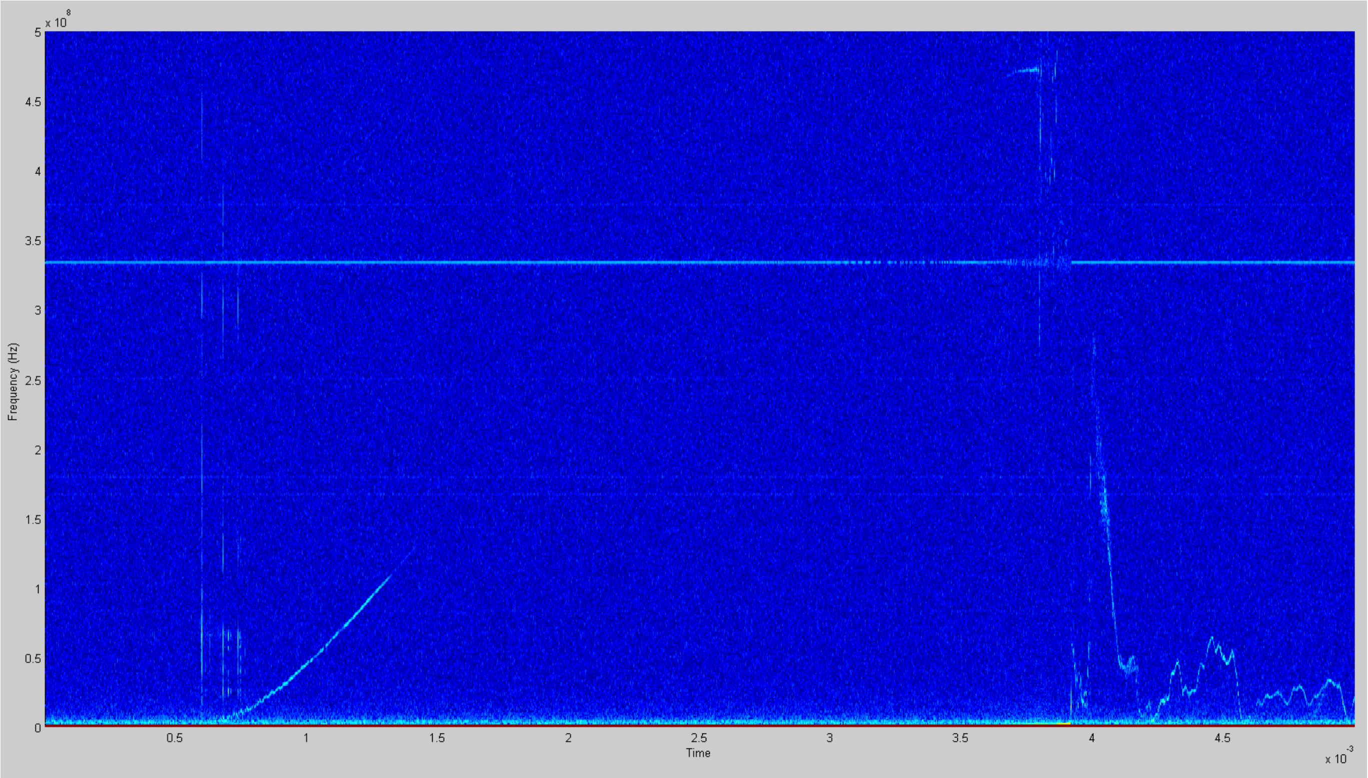
With augment



0.762 mm diameter aluminum wire+6 gm augment+8 kJ input energy

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Shots for just velocity measurement

Shot no	Energy (kJ)	No. of wires	Wire size (inch)	Peak Velocity (m/s)
1	3.2	1	0.032	124
2	6.4	1	0.032	148
3	9.6	1	0.032	150
4	9.6	2	0.032	156
5	9.6	4	0.032	134
6	9.6	1	0.060	146
7	15.8	3	0.032	160
8	8	1	0.032 with 6 gm augment	366

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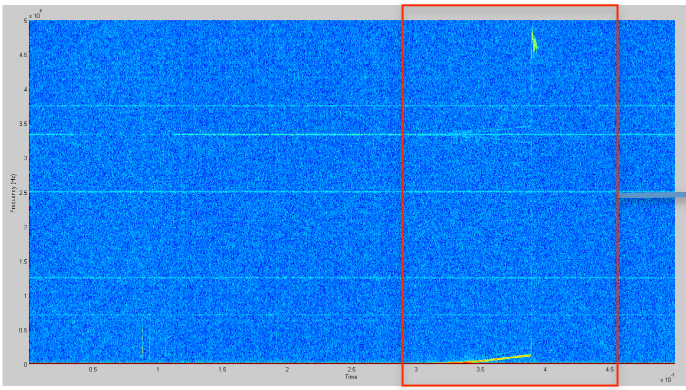
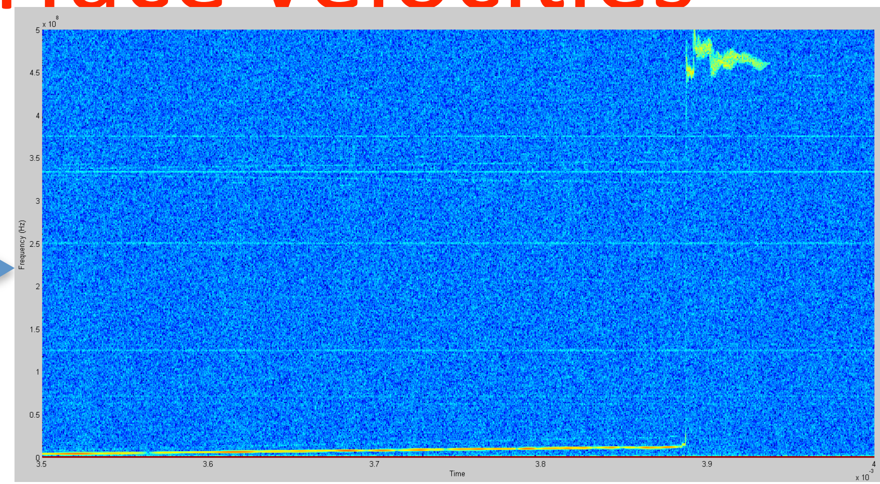
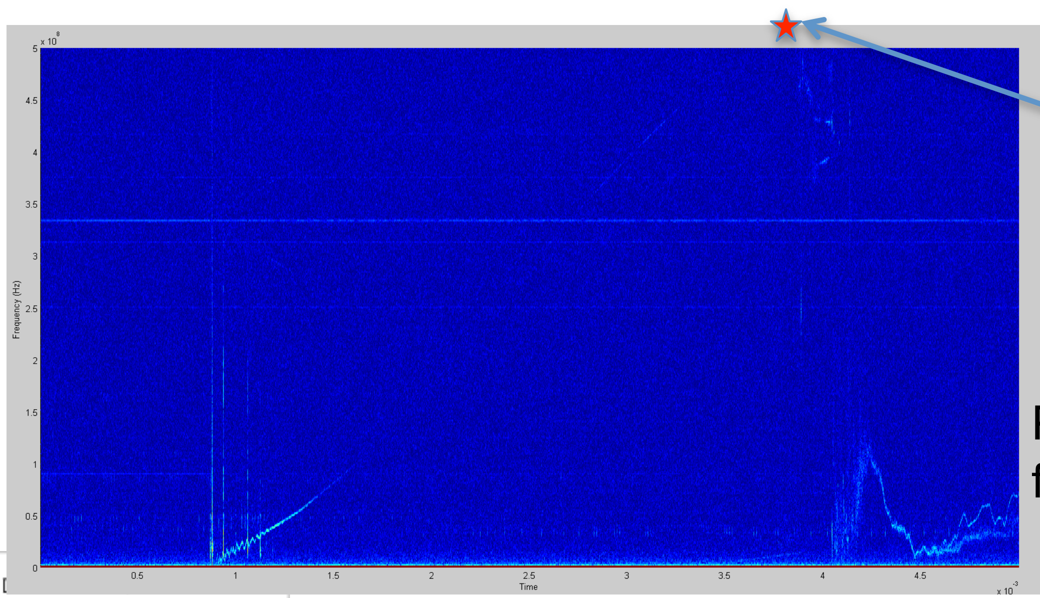
Impact and free surface velocities





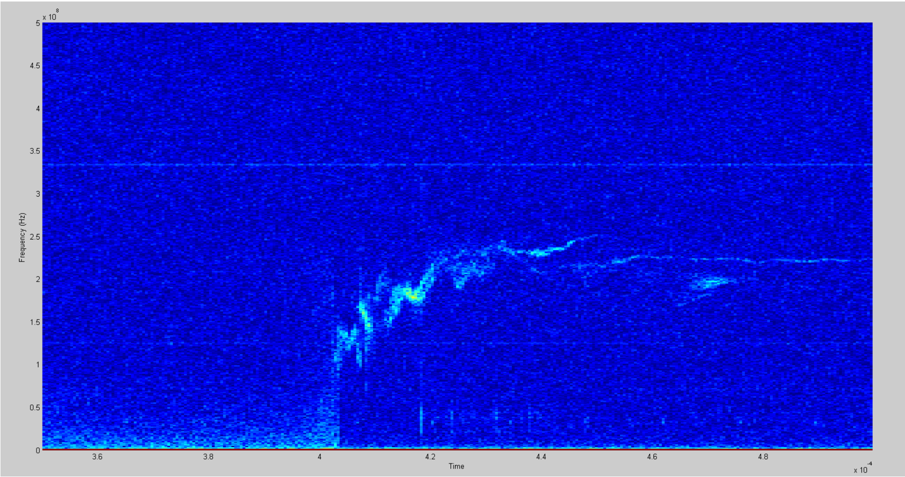


~impact~400m/s

Free surface velocity~370m/s

Particle velocity =1/2* Constant free surface velocity (Assumed)

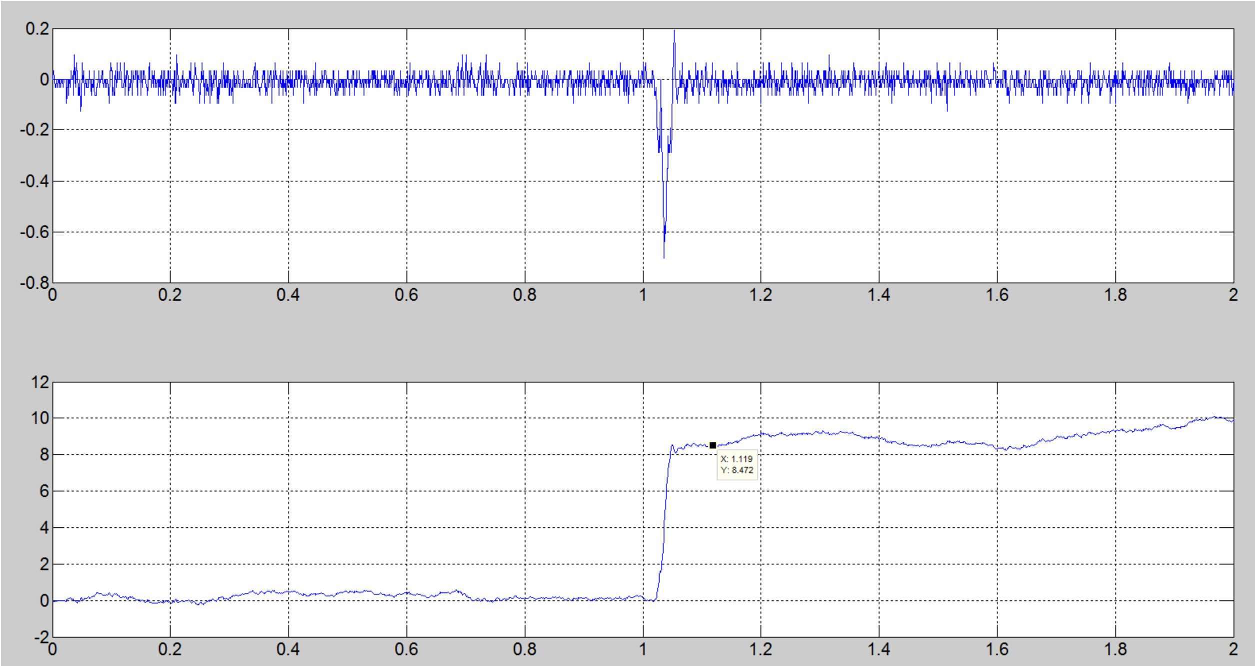
Calibration shot



Free surface velocity ~ 150 m/s

P = 274 Mpa

$$\int V(t)\,dt = 8.5\ \text{V}\mu\text{s}$$



Hence:

Q/A=8.5/RA

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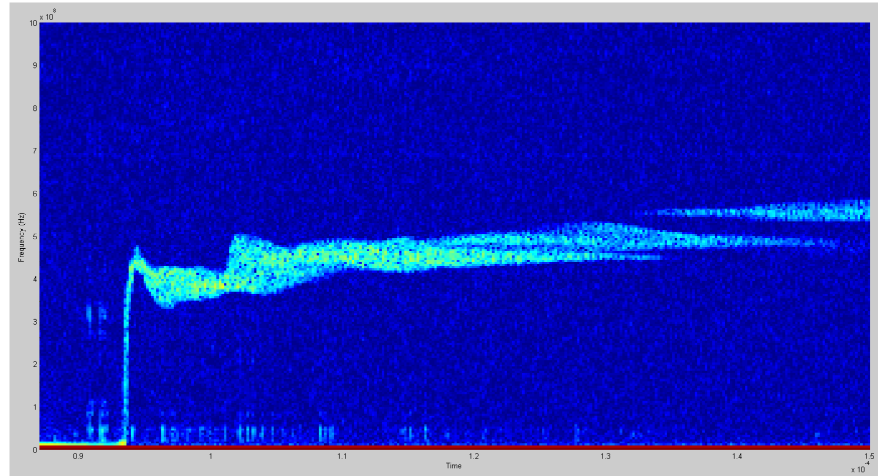
Calibration shot

Free surface velocity ~ 400 m/s

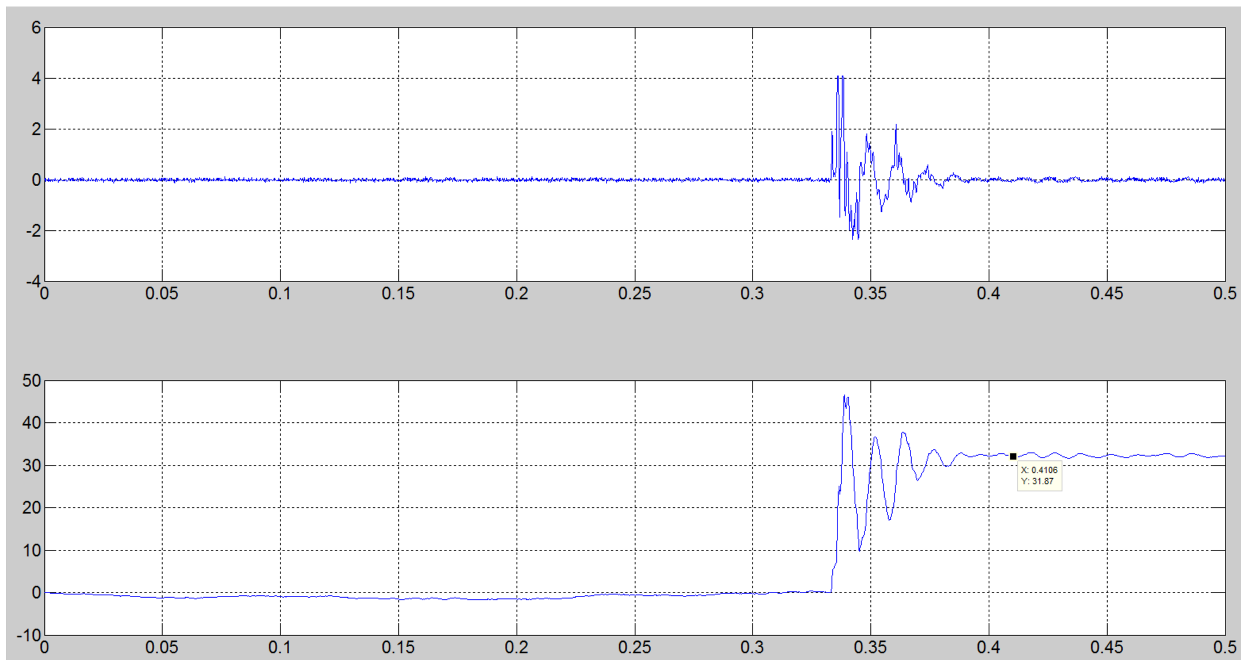


P = 730 Mpa

$\int V(t)\,\mathrm{d}t$ **= 31.8 Vμs**

Hence:

Q/A=31.8/RA



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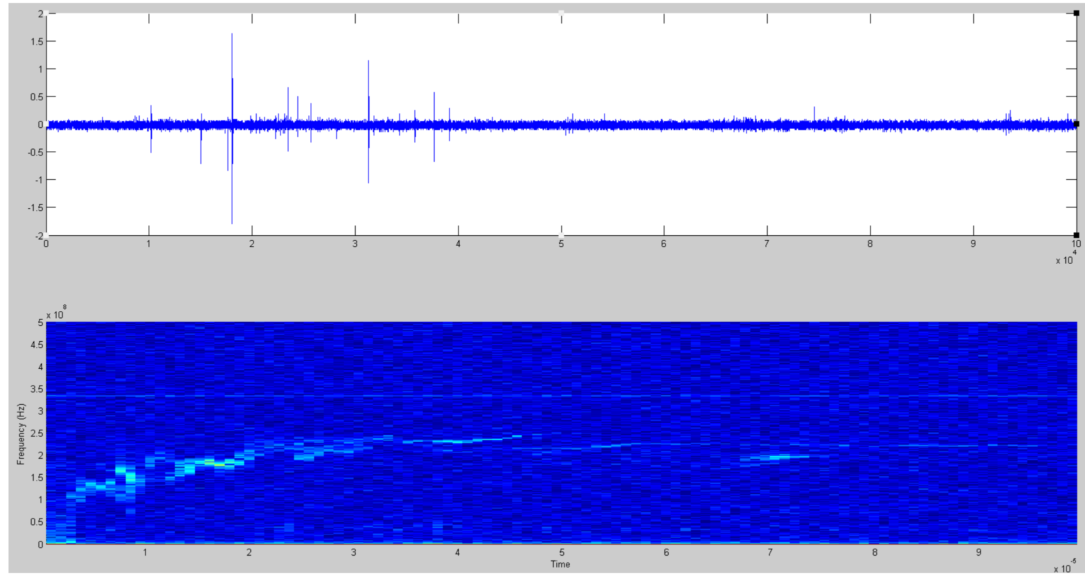
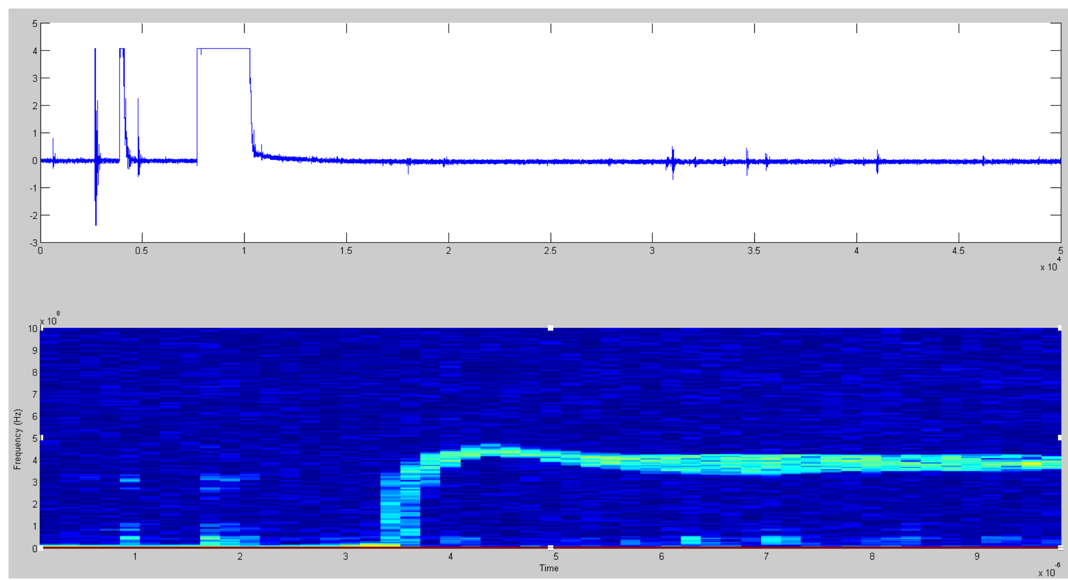
Issues

- Inconsistency in pressure start
- Electrical connections
- Obliquity of impact
- Glue up of the sandwich done by hand
- Statistics





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Conclusions and further work

- Full travel of projectile was measured in case of non augmented shots
- PVDF gauges have been roughly calibrated below 1 GPa
- More calibration shots needed
- Different target and projectile materials can be used to calibrate at different pressures

References

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Questions?

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