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# **Manufacturing Applications of Exploding Foil and Wire and use of PDV as a Diagnostic Technique**

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## ACKNOWLEDGEMENTS

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*Slides, ideas and work conveniently borrowed from:*

Geoff Taber, Huimin Wang, Steve Woodward, Glenn Daehn, Jason Johnson and Emma

*Thanks to:*

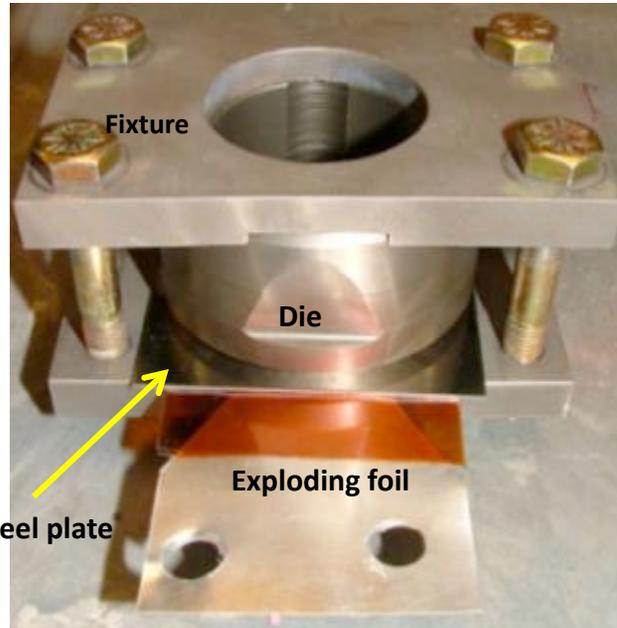
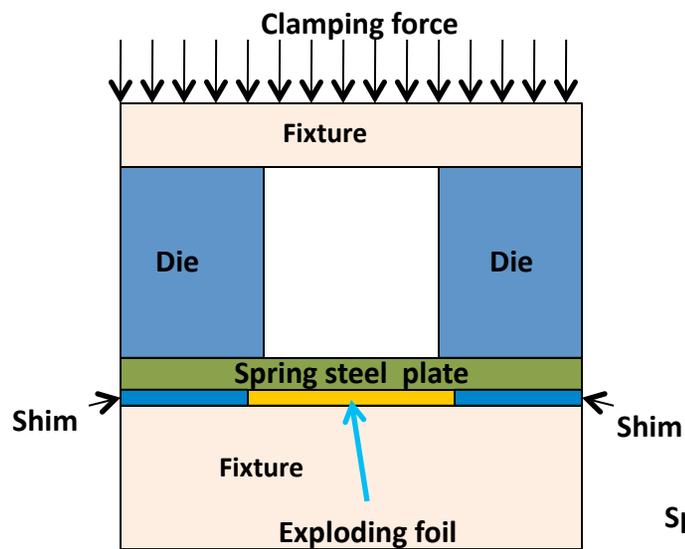
Jerry Stofleth, Sandia National Labs

Jim Dykeman, Honda Research

Andrew Skrepnek, Summo Steel Corporation

# SHEARING

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For spring steel

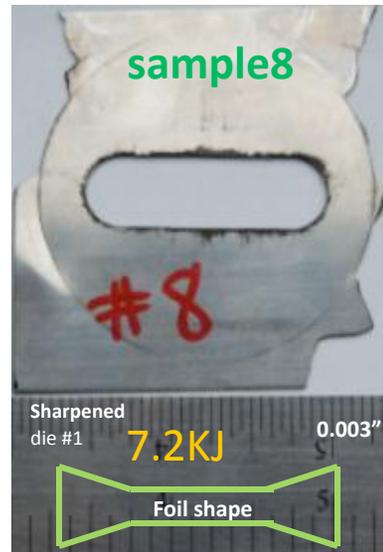
Dies



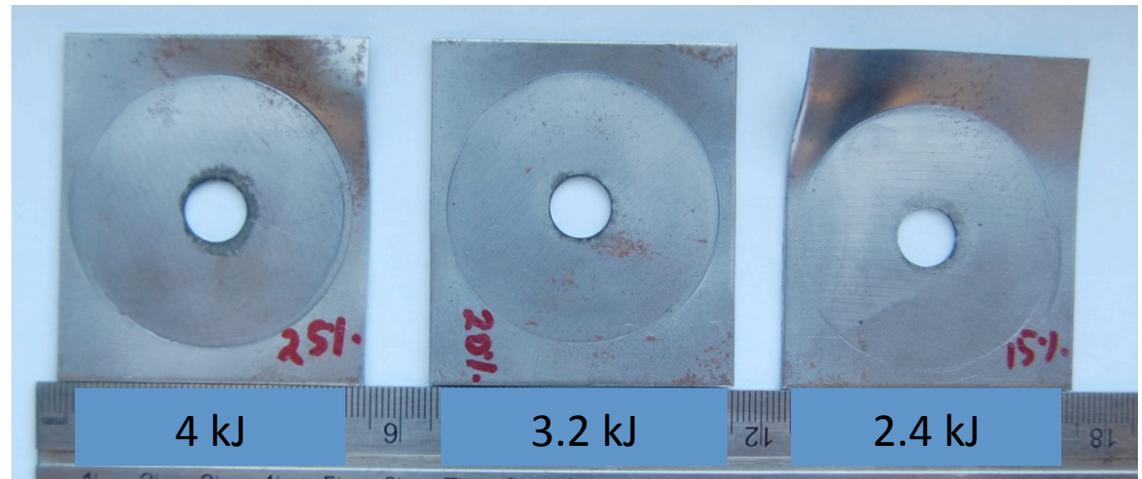
For TRIP Steel

## SHEARING: Some results

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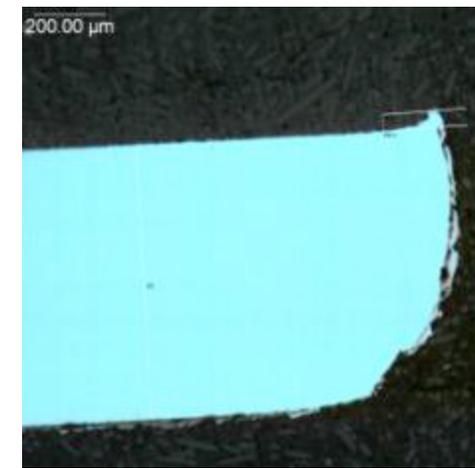
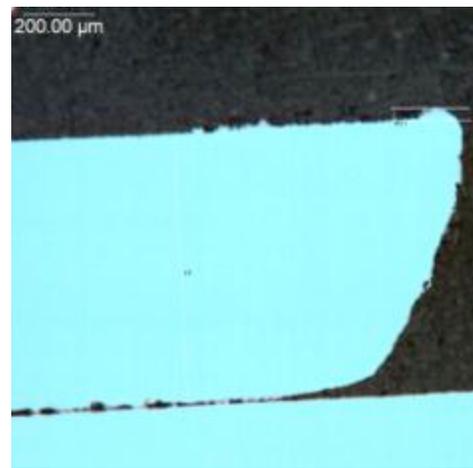
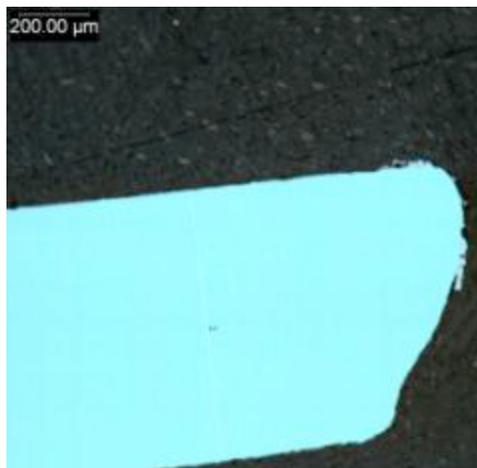
**Velocity of the  
Flyer > 400 m/s**



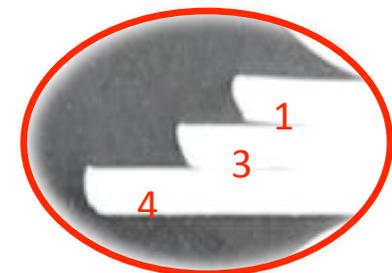
## SHEARING: Optical microscope images

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Courtesy: Huimin Wang



Sample No.	1	3	4
Burr height(μm)	0	33.29	48.03



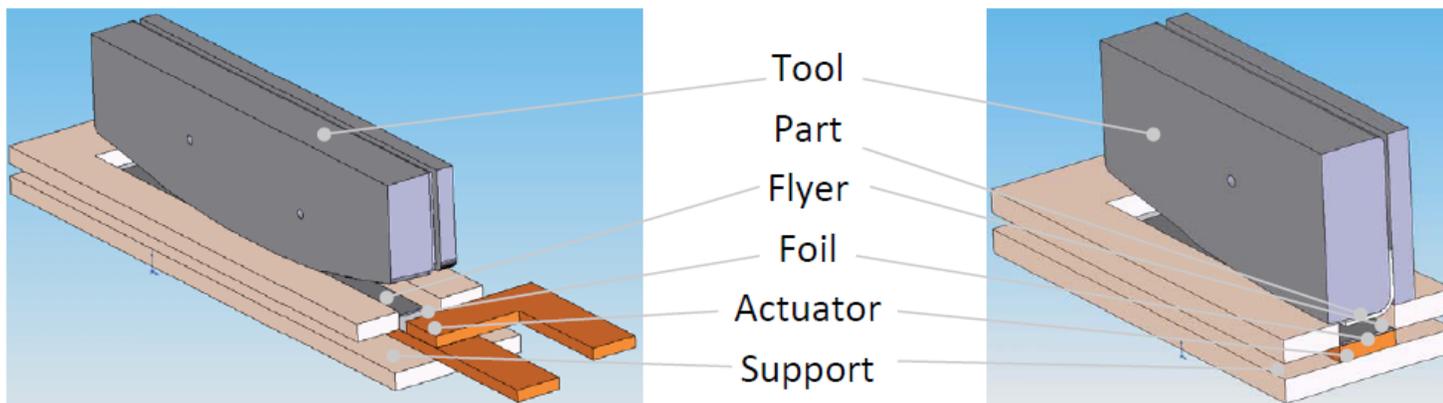
**Burr height will increase with decreasing energy.**

## Forming/Calibration

*Courtesy: Steve Woodward*

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- Capacitor bank discharges large current into actuator
- Actuator transfers current to metal foil
- Foil explodes due to large current, creating a high-pressure wave
- Pressure wave pushes flyer into part at high velocity



### Part is completely within dimensional tolerances

- Part remains in T6 temper condition throughout entire process – no heat treatment required
- Exploding foil process shows significant improvements over hydroforming or electromagnetic forming

- Hydroforming only:

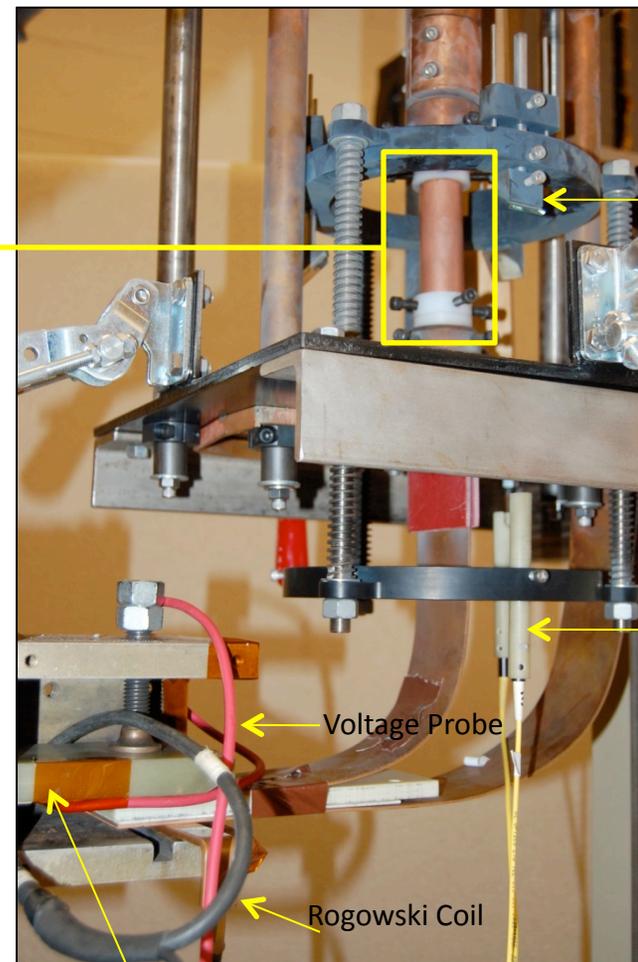
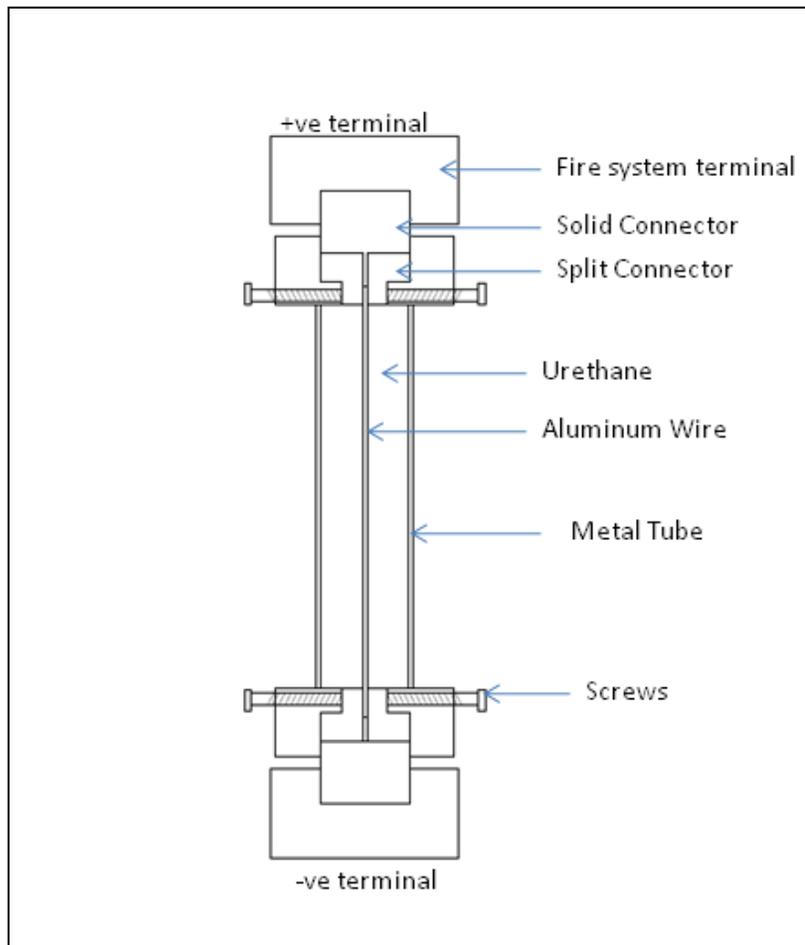


- Hydroforming then explosive foil calibration:



# TUBE EXPANSION

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45 degree mirror

PDV Probe

Voltage Probe

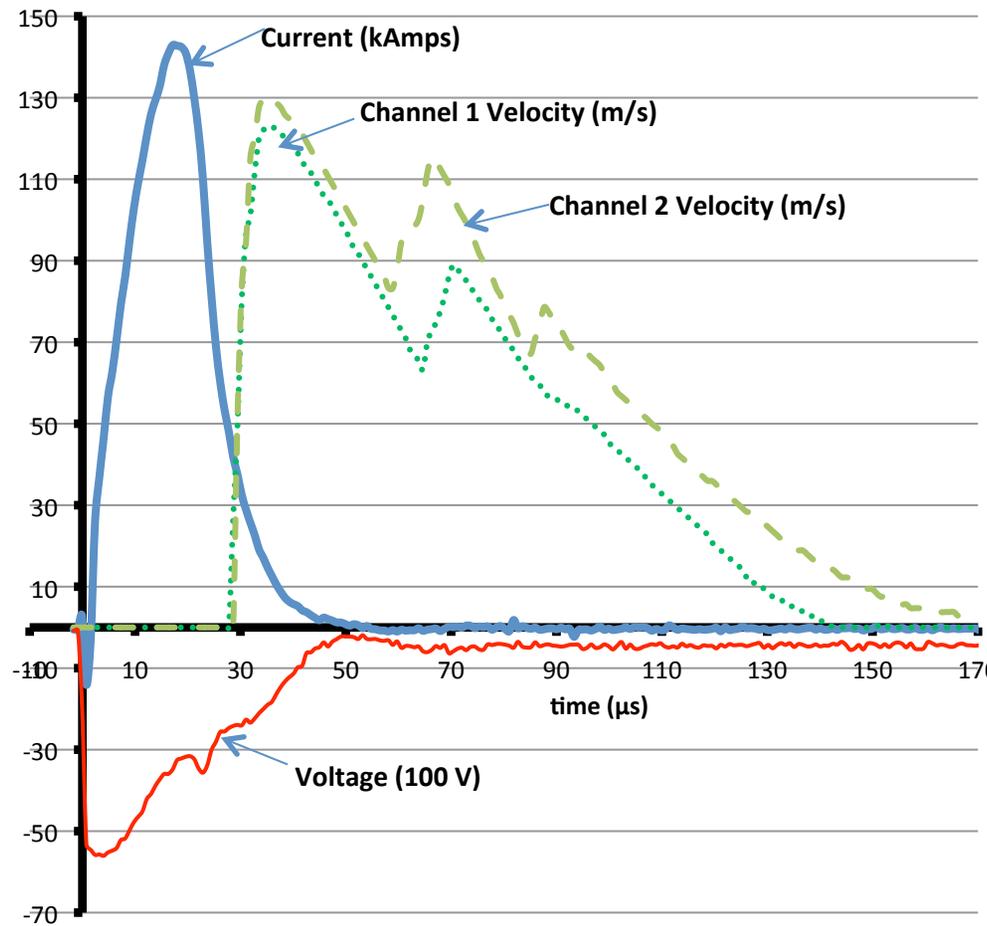
Rogowski Coil

Capacitor Bank Terminal

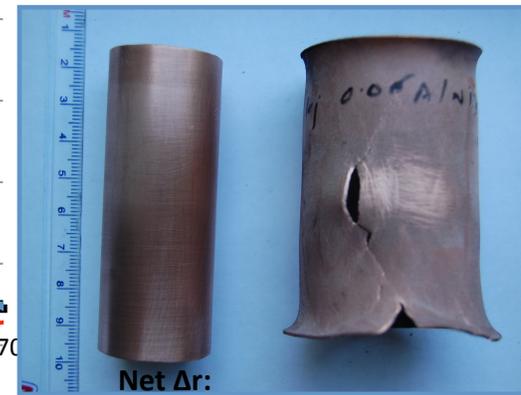
# TUBE EXPANSION:

## Instrumentation-Current, Voltage and Velocity

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9.6 kJ Energy  
Φ0.06" Al Wire  
ID 1" Annealed  
Copper Tube



Net Δr:

PDV: 8.3 mm

Calliper Measurement: 7.6 mm



## CALCULATING PEAK PRESSURE:

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Pressure=Force/Area

Force= Mass\*Acceleration

Acceleration=  $dV/dt$  where V is velocity, t is time

Mass= Density\*Volume

Volume of tube  $\sim$  Area of curved surface\*Thickness

$\Rightarrow$ Pressure= (Density\*Area\*Thickness\*dV/dt)/Area = (Density\*dV/dt)\*Thickness

Sample Calculation:

Density of copper= 8940 kg/m<sup>3</sup>

Thickness of tube=  $1.5875 \cdot 10^{-3}$  m

$dV/dt$ =  $19.6 \cdot 10^6$  m/s<sup>2</sup>

$\Rightarrow$ Pressure=  $8940 \cdot .0015875 \cdot 19.6$  Mpa= 278.1681 Mpa



# TUBE EXPANSION: Result summary

**Peak Pressures!**

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Sl. No)	Energy (kJ)	Wire material	Max Current (kAmps)	Rise Time ( $\mu$ s)	Max Velocity C1, C2 (m/s)	First dV/dt ( $m/s^2$ )* $10^6$	Peak Pressure (Mpa)	Max dV/dt excluding first value ( $m/s^2$ )* $10^6$	Peak Pressure (Mpa)	Final OD (inch)	% Radial Strain	Comments
1	6.4	Al, 0.06" diameter	126	20.4	90,101	40.3	571.9477	19.6	278.1681	1.45	28.8%	
2	6.4	Al, 0.06" diameter	121	19.6	83,79	11.6	164.6301	23.1	327.841	1.39	23.5%	
3	6.4	Al, 0.06" diameter	125	19.6	87	59.5	844.4389	15	212.8838	1.43	27.1%	PDV 2 not working
4	8.0	Al, 0.06" diameter	135	19.6	112, 106	29.7	421.5098	32.3	458.4097	1.6	42.2%	
5	8.0	Al, 0.06" diameter	135	18.8	118, 112	--	--	--	--	1.66	47.5%	Noisy velocity data
6	9.6	Al, 0.06" diameter	135	17.2	70,66	41.4	587.5592	24.1	342.0332	1.35	20%	Current Shortage through tube
7	9.6	Al, 0.06" diameter	143	17.2	123, 131	29.7	421.5098	38.1	540.7247	1.72	52.8%	Cracking Begins
8	8.0	Al, 0.03" diameter	70	8.9	77,70	21.4	303.7142	28	397.383	1.65	46.6%	
9	8.0	Al, 0.08" diameter	157	24.5	16,19	--	--	--	--	1.22	8.4%	noisy velocity data
10	8.0	Cu, 0.06" diameter	154	22.8	24,23	--	--	--	--	1.28	13.8%	Noisy velocity data



# CONCLUSIONS

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- Very high pressures to move workpieces very fast
- PDV can be used for validating models for this process
- Quick estimates of pressure by PDV
- Optimization of process: velocity of impact, travel distance before impact etc.