an electromagnetically driven metalworking press

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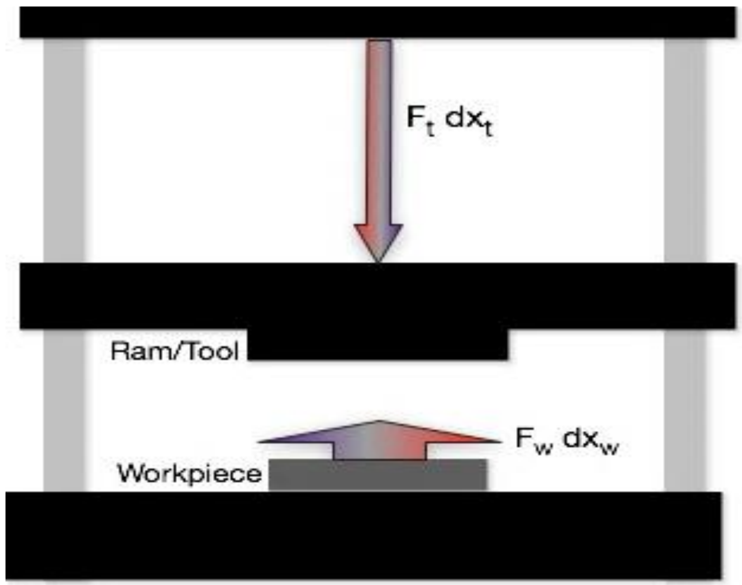
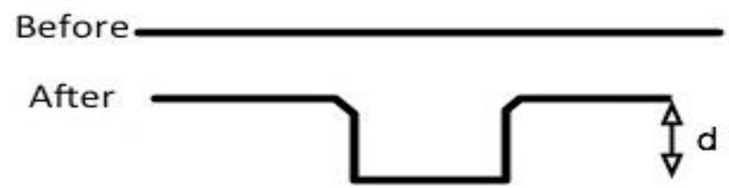
The approximate averaged strain rate that will be developed can be represented as: $\dot{\varepsilon} \approx \frac{\overline{\varepsilon}}{\Delta t} \approx \frac{\overline{\varepsilon}\, v_{max}}{2d}$



Representation of a kinetic press with ram/tool impacting workpiece



Schematic of flat sheet before and after forming in feature of depth, d.

Presses using the stored energy of springs or compressed gas have been developed by several manufacturers, velocities generally modest, few m/s. Motivated to develop this press to explore strain rate affects in 3 regimes; quasi-static, 10 m/s and 100 m/s.
If a feature is 1mm deep and this produces an average Mises strain of about unity, a typical press with a speed under 10 cm/s will produce a strain rate under 25 s^{-1}, whereas a punch speed of 10 m/s will give a strain rate near 2.5 x 10^3 s^{-1}, and a punch speed over 100 m/s provides strain rates over 2.5 x 10^4 s^{-1}

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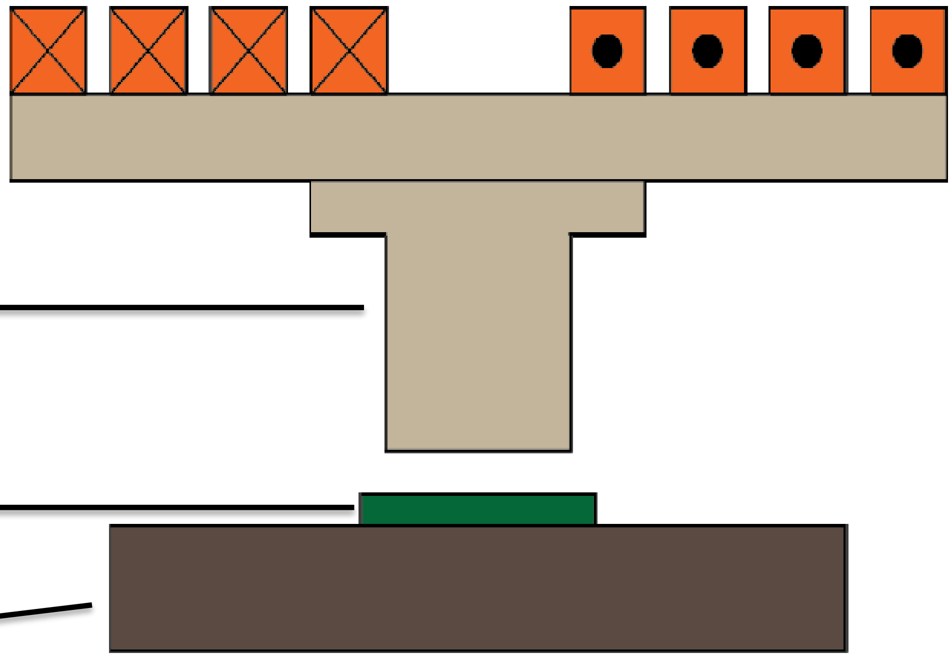

Schematic representation of the electromagnetic press

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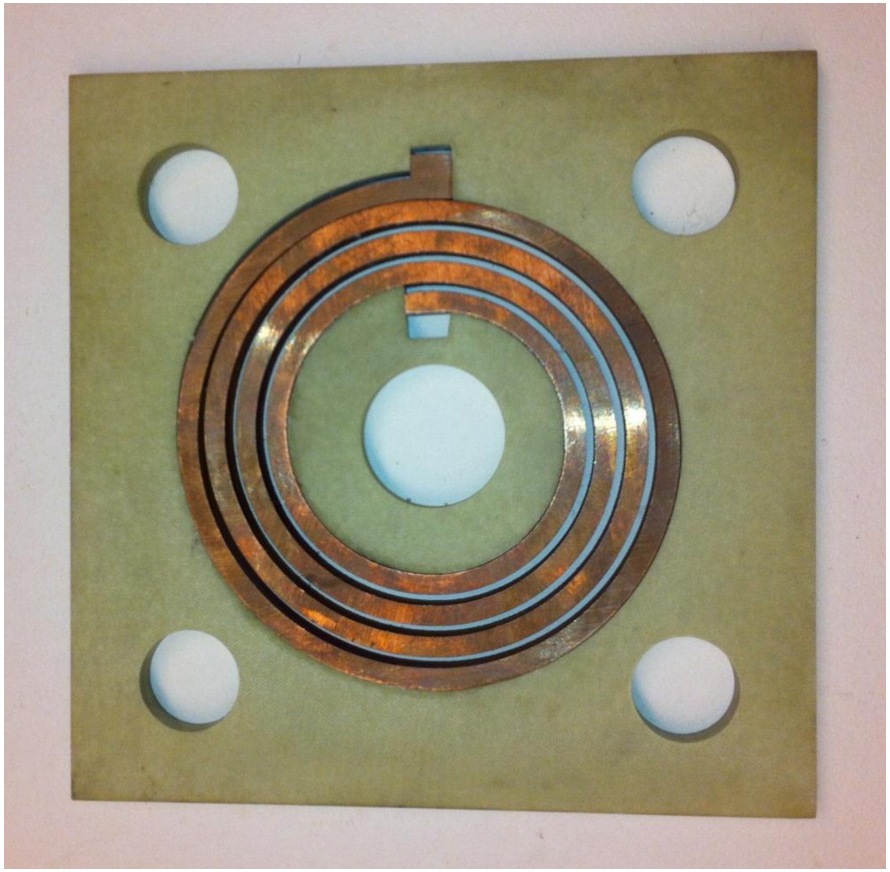

pieces & parts

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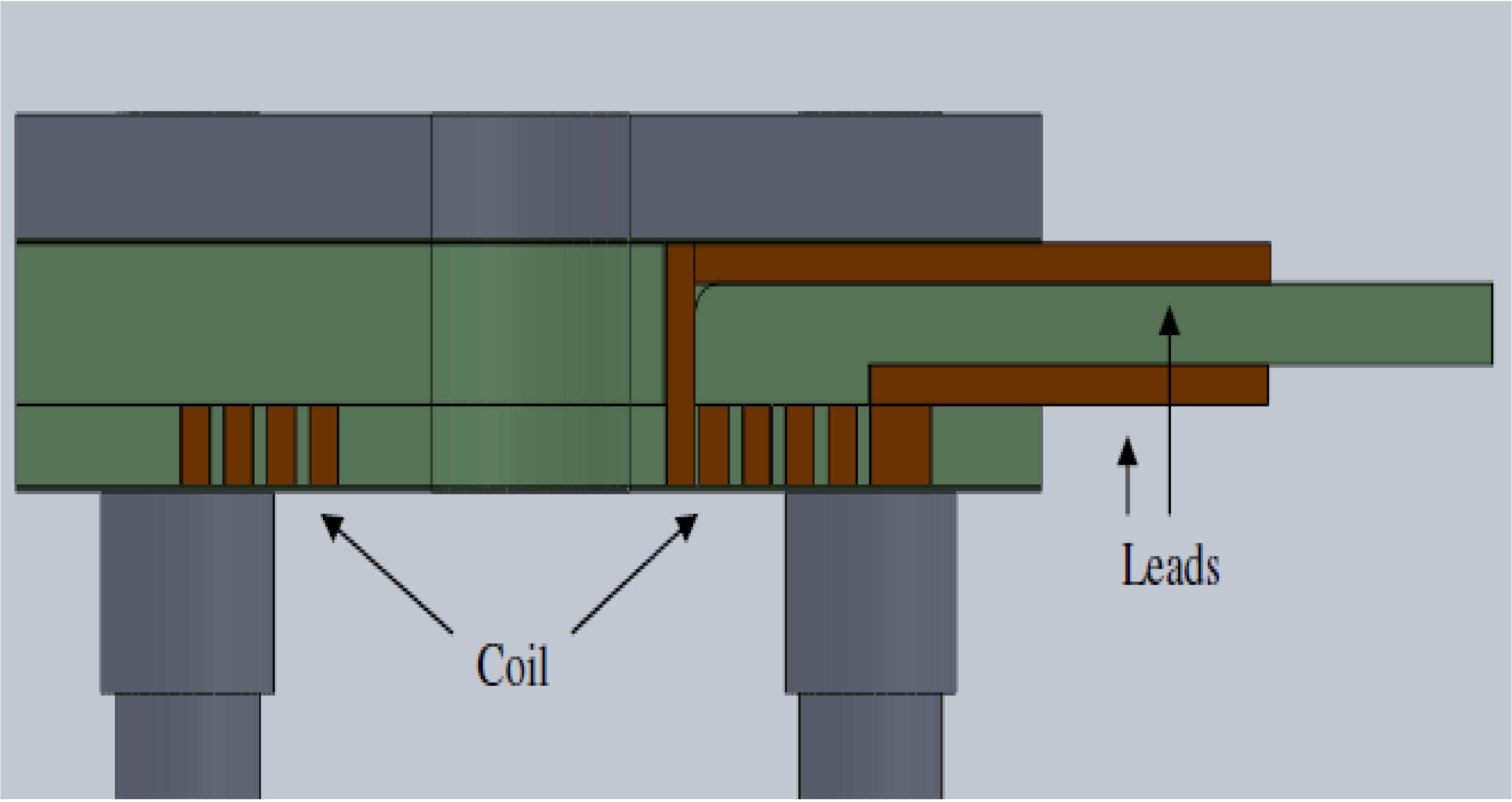

Coil system showing copper primary coil and reinforced phenolic backing

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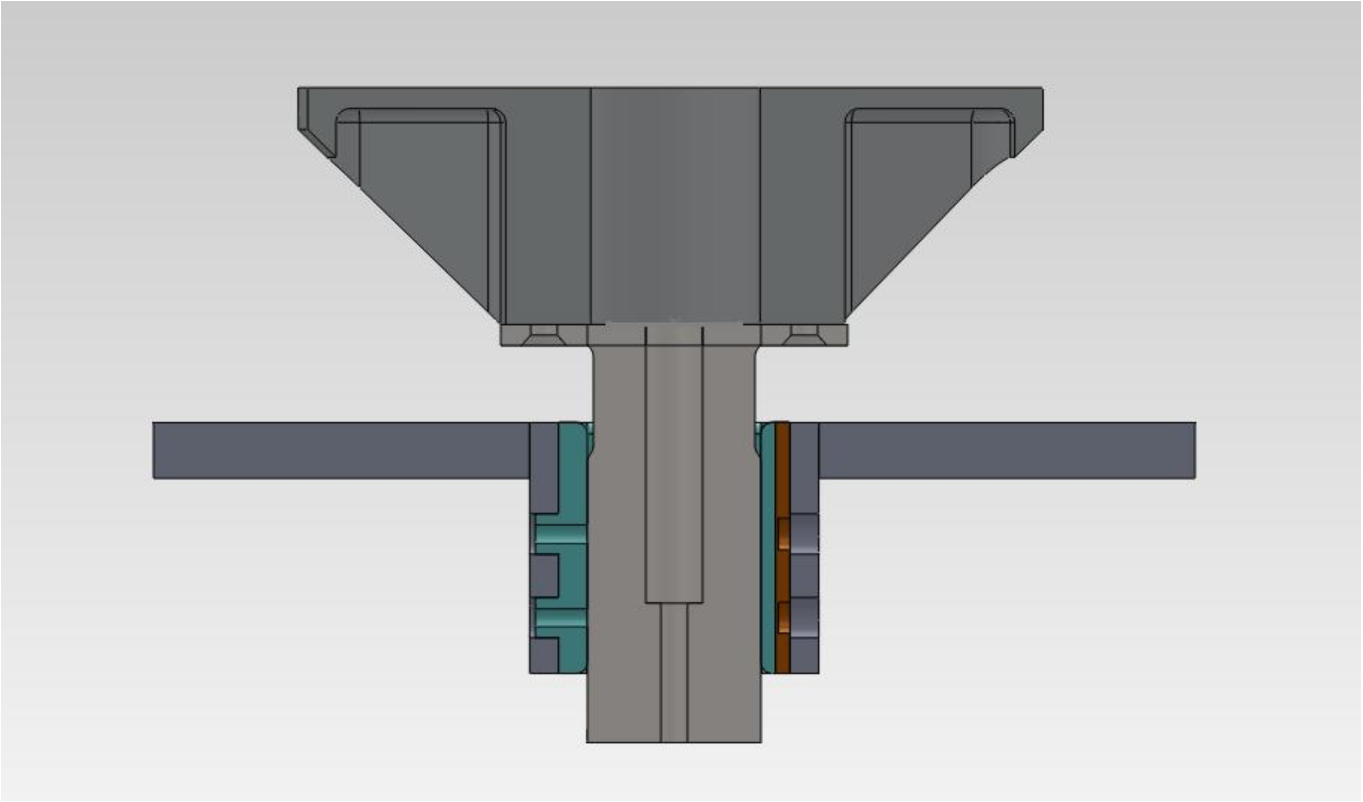

EM Press bushing, post and flyer assembly section view, with adjustable UHMW bushing on the right

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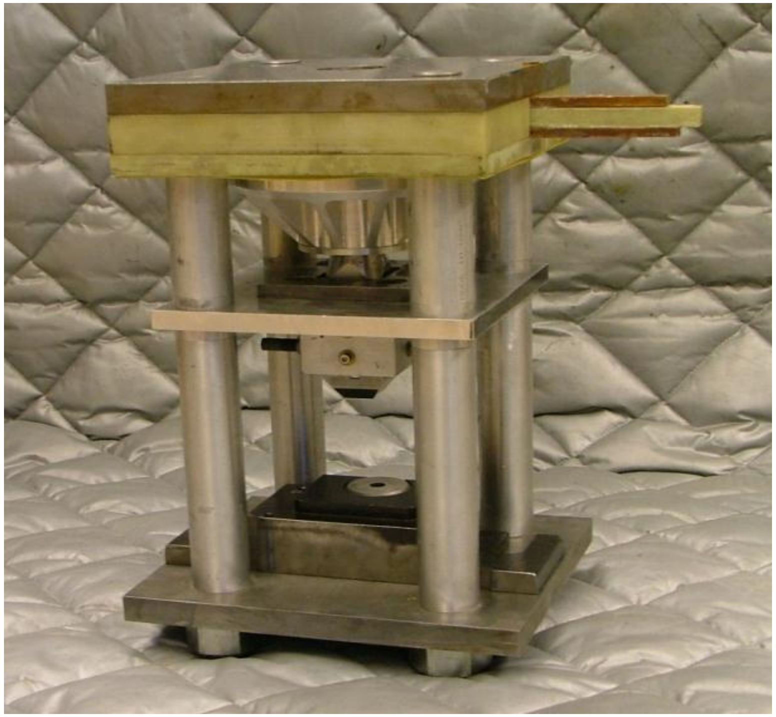

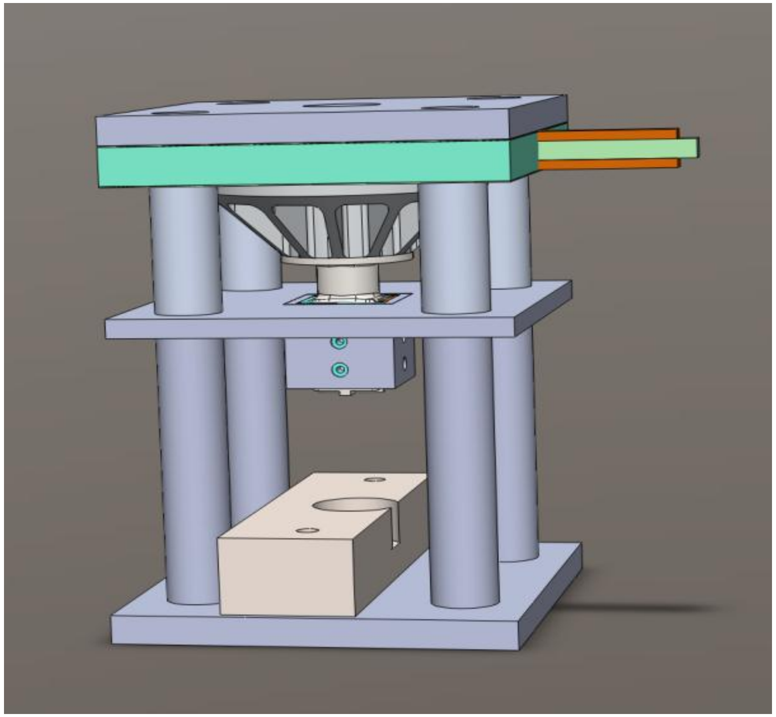

Actual embodiment of the high speed press and 3-D CAD rendering

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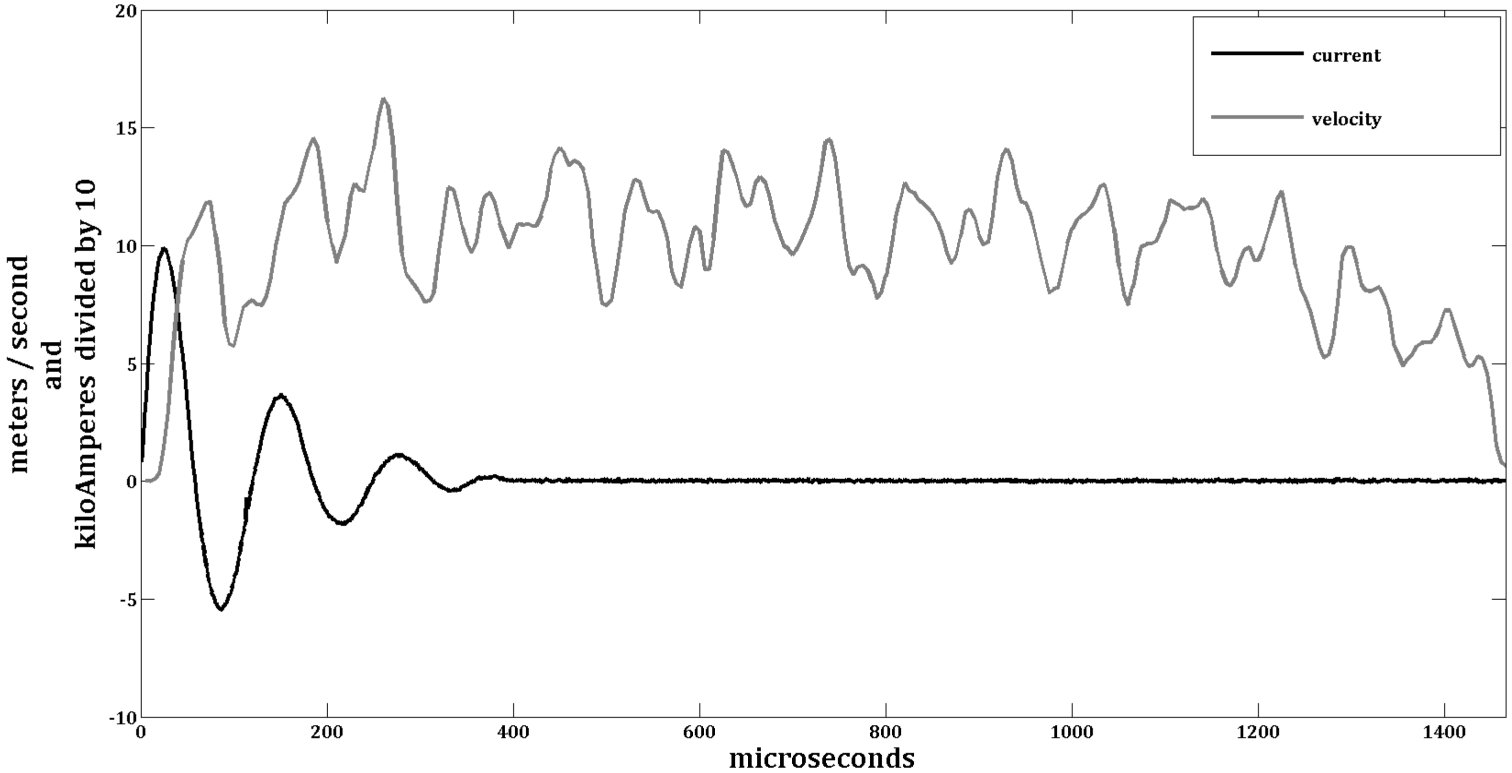
laser velocimetry and current monitoring



Launch characteristics of the tool post in a 4 kJ discharge.
Average velocity is near 10m/s

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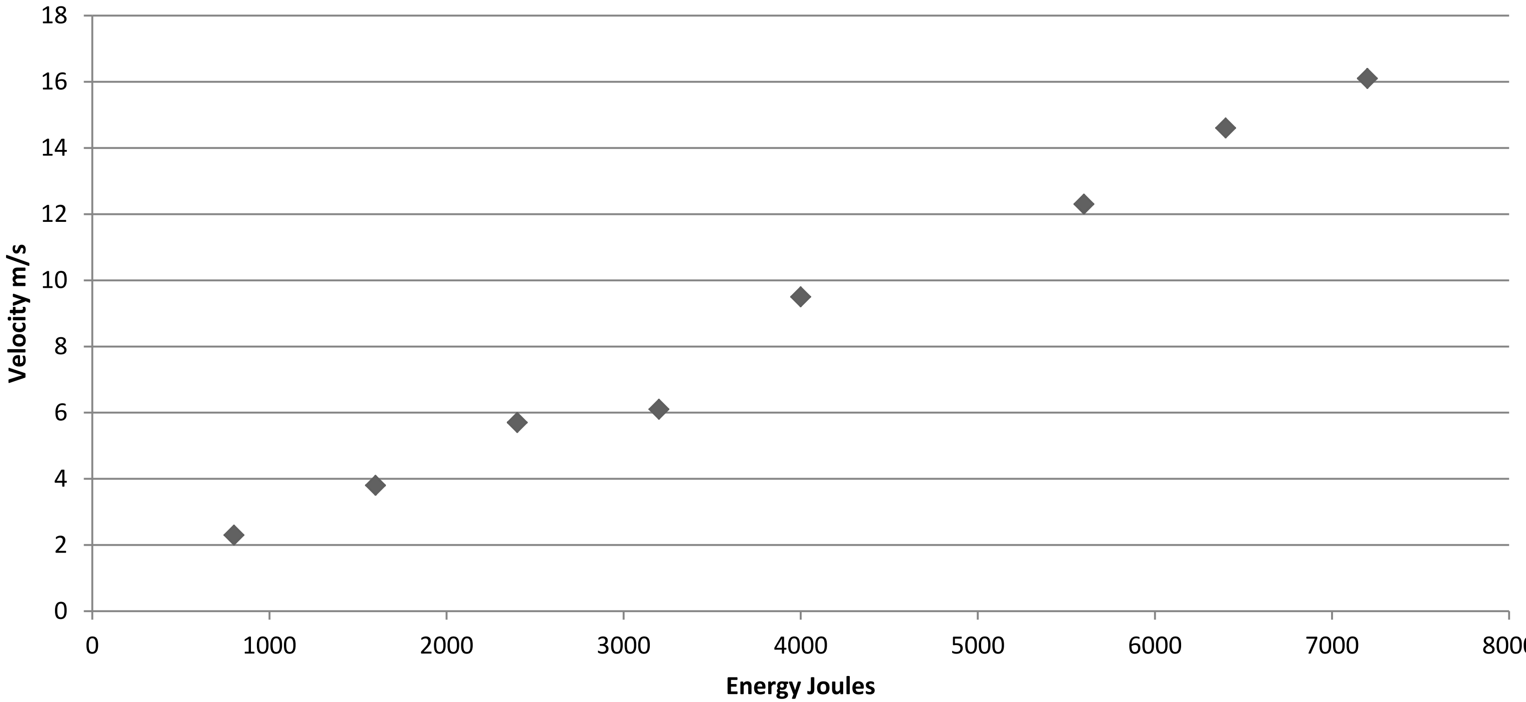
$\frac{1}{2} MV^2 \neq \frac{1}{2} CV^2$; variable and dynamic coupling



Ram velocity increases fairly linearly with input energy. The maximum input energy used was 7.2 kJ resulting in a velocity of 16.1 m/s.

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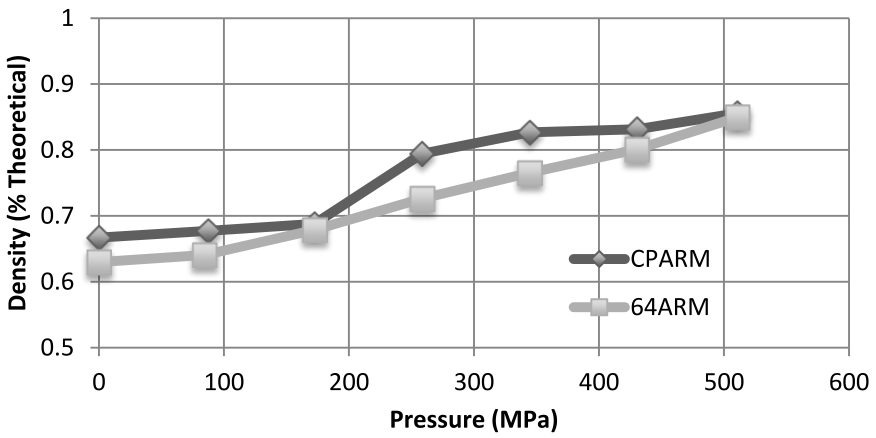
The press has been used in a variety of applications. In particular, the processes of powder consolidation, sheet metal forming, coining and shearing have been examined. Here we will highlight applications in powder consolidation and sheet forming.



Density as a function of pressure for the compaction of partially-dense roll compacted sheet in compression between flat platens.
CPARM refers to commercial purity powder, and 64 is a Ti-6Al-4V alloy, both from the Armstrong powder production method.

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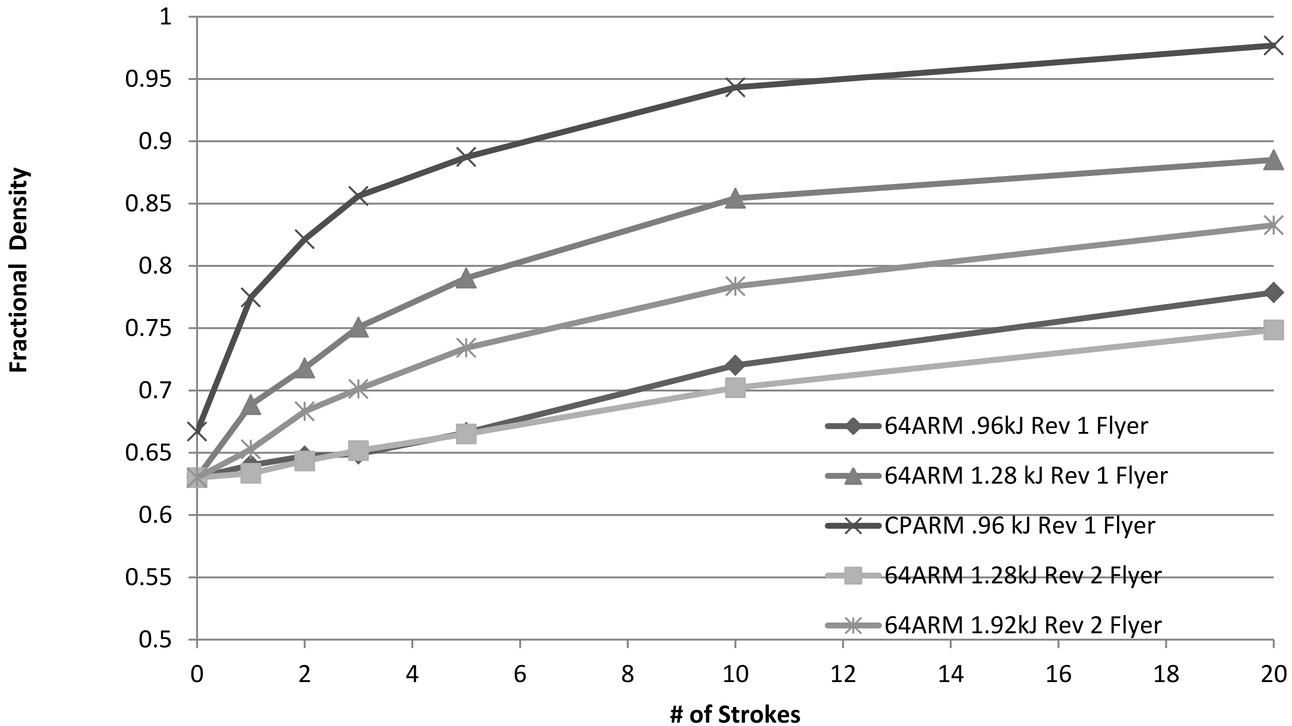

Compacted densities as a function of number of strokes for roll compacted partially dense titanium sheets.

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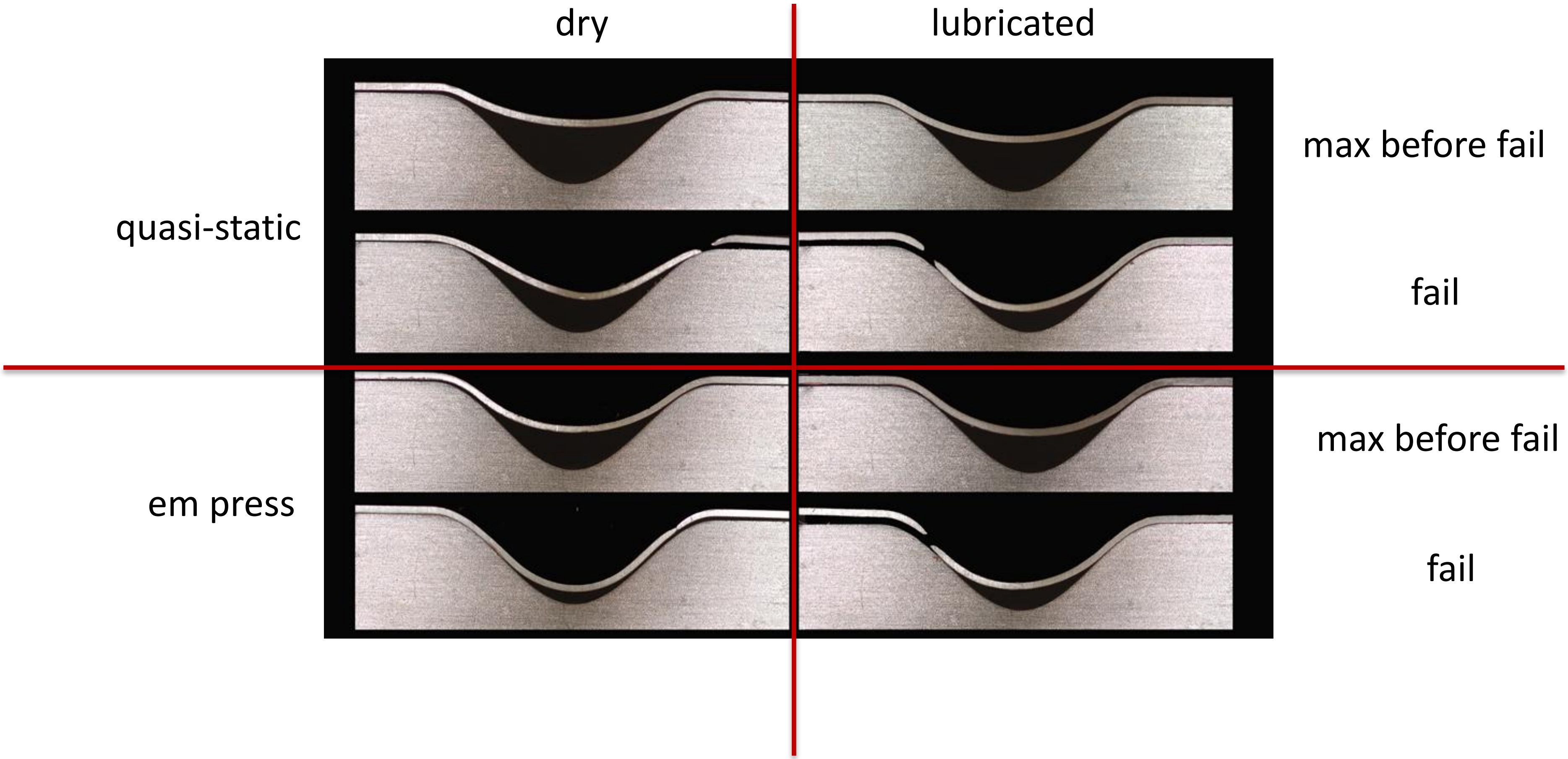

Cross-sections of 3003 H-19 aluminum stretched into channels in nearly plane strain using a urethane pad and a one-sided steel die. Conditions just prior to and just after failure are noted in each case.

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In several operational respects the electromagnetic press is comparable or superior to methods based on other types of equipment. In particular, this work demonstrated enhanced plasticity of sheet aluminum by urethane pad forming in comparison to quasi-static methods and improved consolidation in high speed impact pressing versus quasi-static conventional pressing.

There are high accelerations associated with this device that induce severe shock loads to the apparatus. For example, a 4kJ input to the driving coil accelerates the tool post to 10m/s in about 50μs, which is 200,000G. In the application of coining, acceleration on impact can be more than double that. Such loading must be considered in the design in order to minimize fatigue and stress concentrations.

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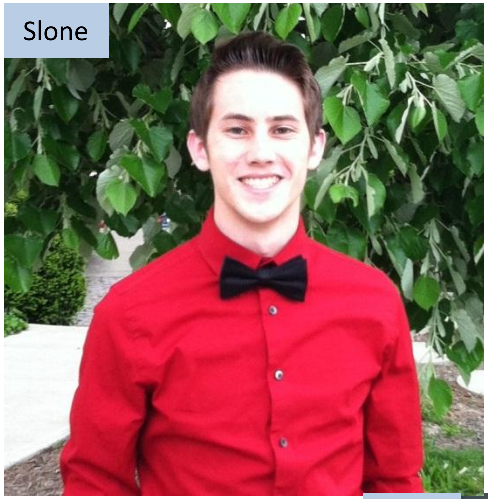
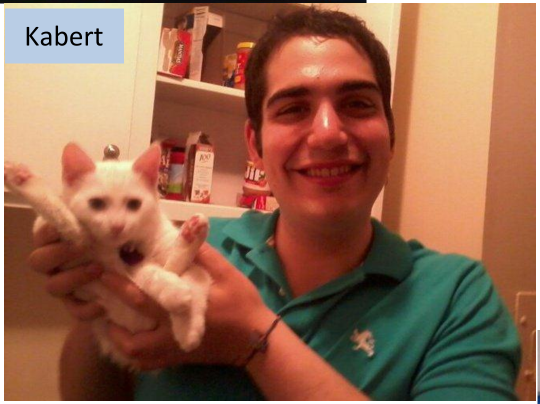
Daehn



Slone

Windholtz



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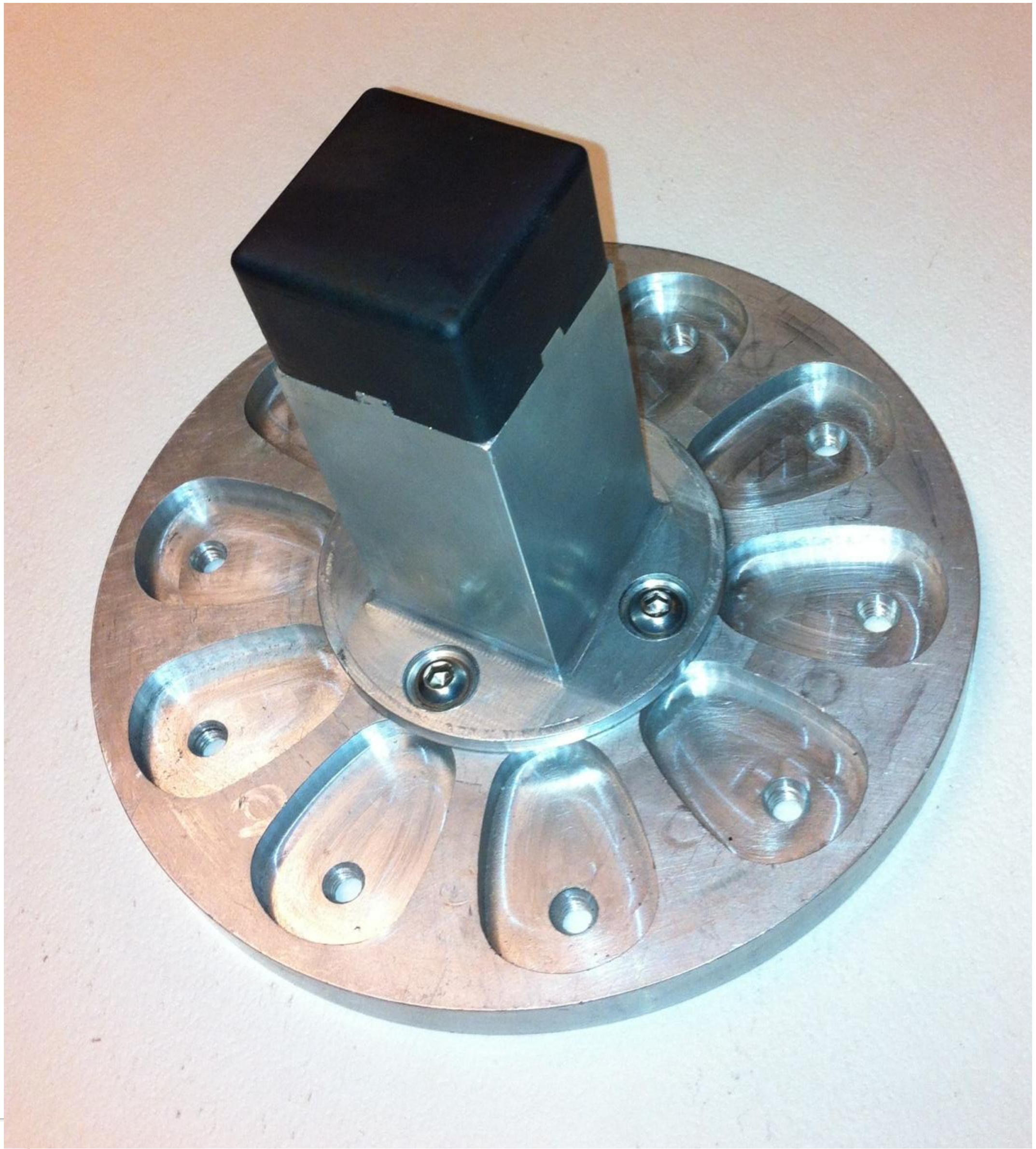

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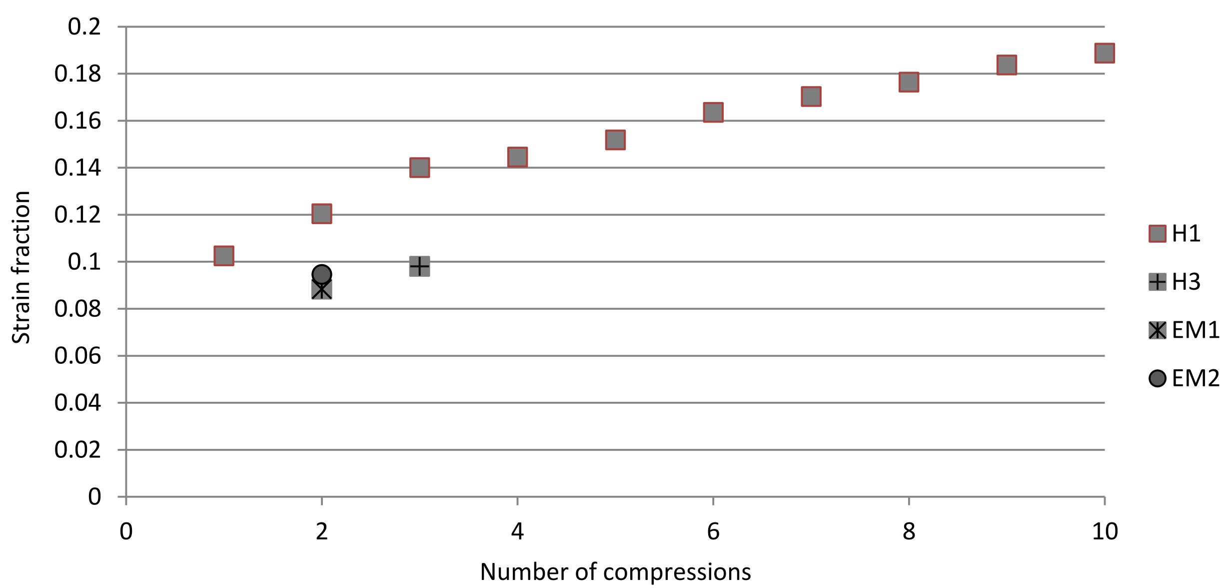
Coining

In the cases of static and slow loading, significant pressures are necessary to plastically form surface features in harder metals. Typical coining operations occur at pressures in the range of 500MPa. The OSU EM press has also been used to investigate such processes. A U.S. ten cent coin (dime) is about 17.85mm in diameter, under a static load of 32,000 kg (127MPa initial) the diameter will increase to ~19.5mm, a strain of 9%. Iterative quasi-static loading to the same force increases the diameter further. Similar strains per stroke were obtained with the electromagnetic press with impacts at 10m/s (input energy of 4.0kJ). Figure 10 shows the trend of iterative quasi-static compressions (series H1)
in comparison to unique 2 and 3 compression data points.



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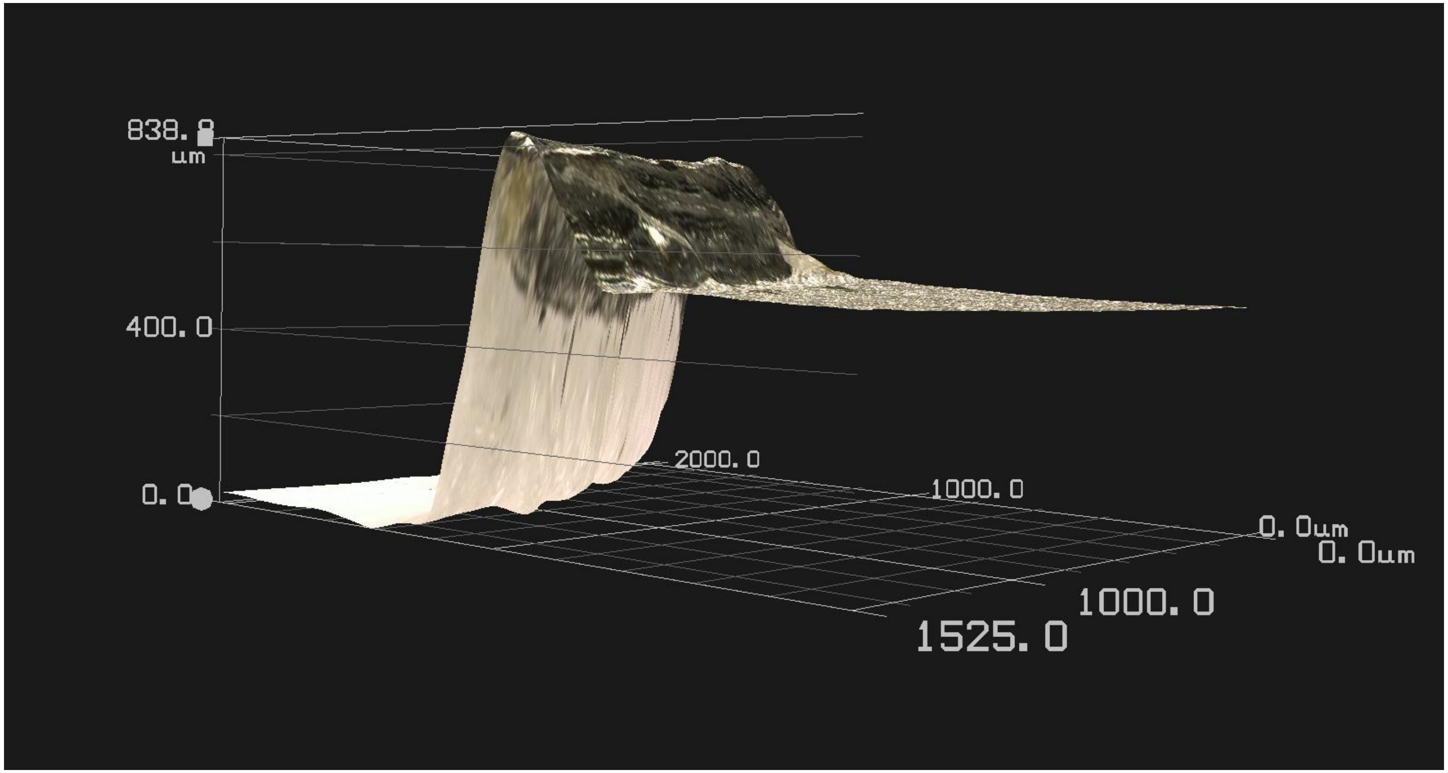
Shearing

Two methods of shearing were examined using the EM press, punchless urethane pad and matched punch and die. Urethane pad punching into a commercial 10mm round die was possible with 3000 series H4 aluminum sheet up to 0.635mm using impact velocities of 10m/s.

Burr height and edge uniformity of pad and die cutting was better than quasi-static matched punch and die. Two types of higher strength "galvannealled" steel were sheared at the same energy using a matched punch with the die;. 0.7 mm JAC270F and 0.6mm JAC590Y.

Burring was not significantly improved over quasi-static methods. Both techniques (quasi-static & impact) of punch and die shearing had significant burr heights of 200-800 µm and non-uniform edge quality. Figure 11 is a digitally reconstructed profile micrograph of a sheared edge section.

Burr height above the top plane is about 290µm.



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