Mechanical Engineering
UNIVERSITY OF COLORADO BOULDER

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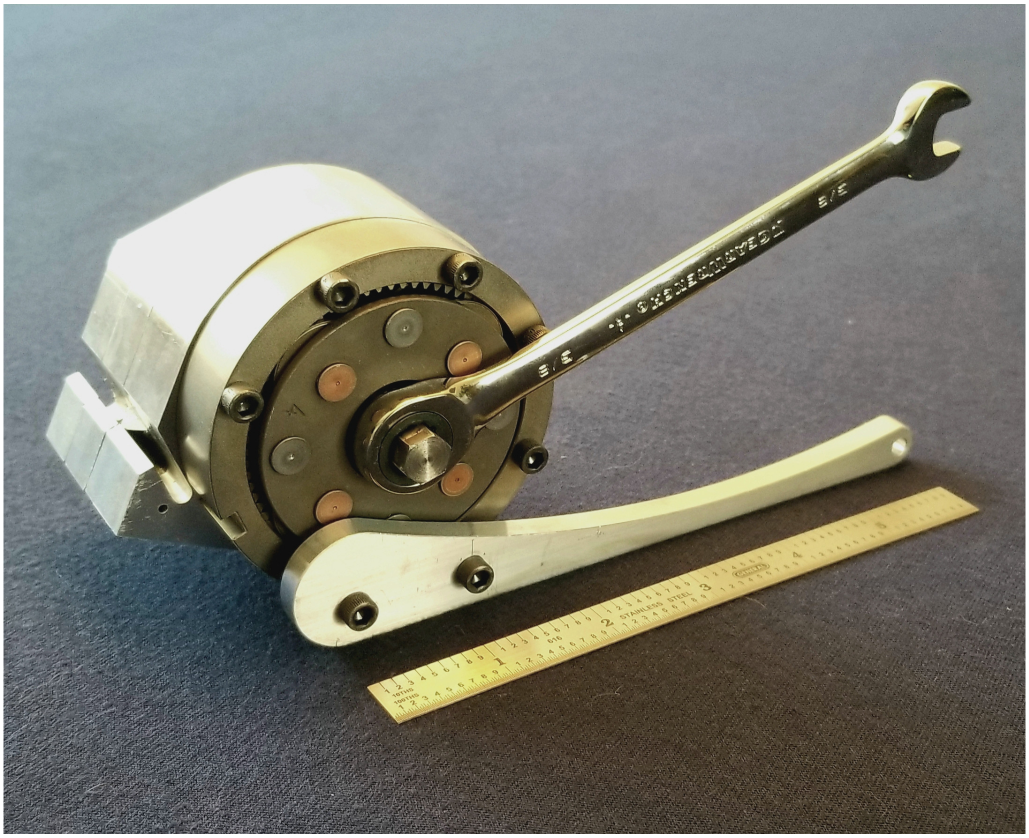
Miniature HAZMAT Crimp and Seal Tool

Sponsored by Los Alamos National Laboratory
Team Directed by Bill Vanderheyden

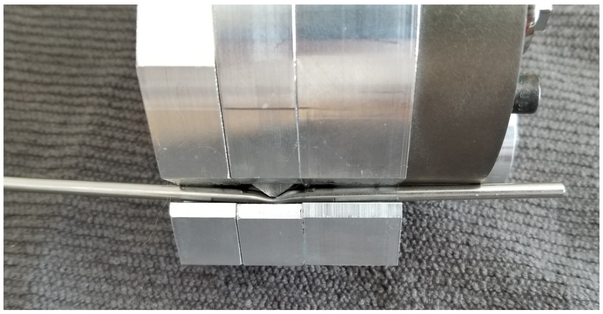


Introduction

Los Alamos National Laboratory utilizes ⅛” stainless steel tubing in conducting experiments. The contents of this tubing can be hazardous and under high pressure. In order to maintain a safe work environment for the lab personnel when an emergency situation arises, HAZMAT operators may need a reliable tool that can stop fluid flow through the tubing.

This project provides a prototype tool allowing HAZMAT operators to crimp and seal ⅛” stainless steel tubing to a leak rate less than 10^{-4} cc/s without the use of electricity while being small enough to fit in the confines of various lab areas.

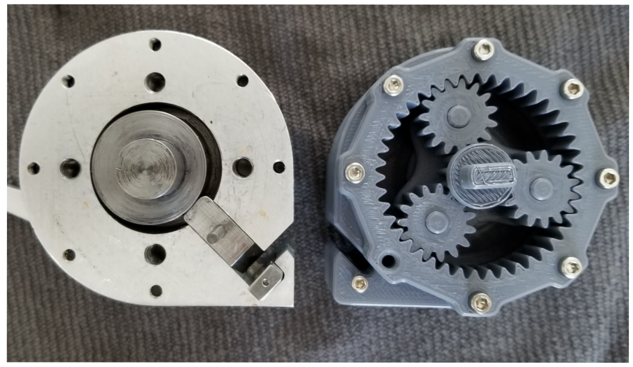
Overview



A length of ⅛" stainless steel tubing being crimped

Solution: The Miniature HAZMAT Crimp and Seal Tool is a small tool that utilizes a planetary gearbox mechanism and cam to generate a crimping force over 2000 lb. This force is directed into the ⅛" stainless steel tubing through an interchangeable hammer and anvil. These easily swapped out components allow for crimp optimization and tool maintenance. The tool body fits within a 3" cube and is manually operated by removable 6" handles. The main body of the tool is composed of 7075-T6 aluminum alloy and the cam, hammer, and anvil are composed of 4140 alloy steel.

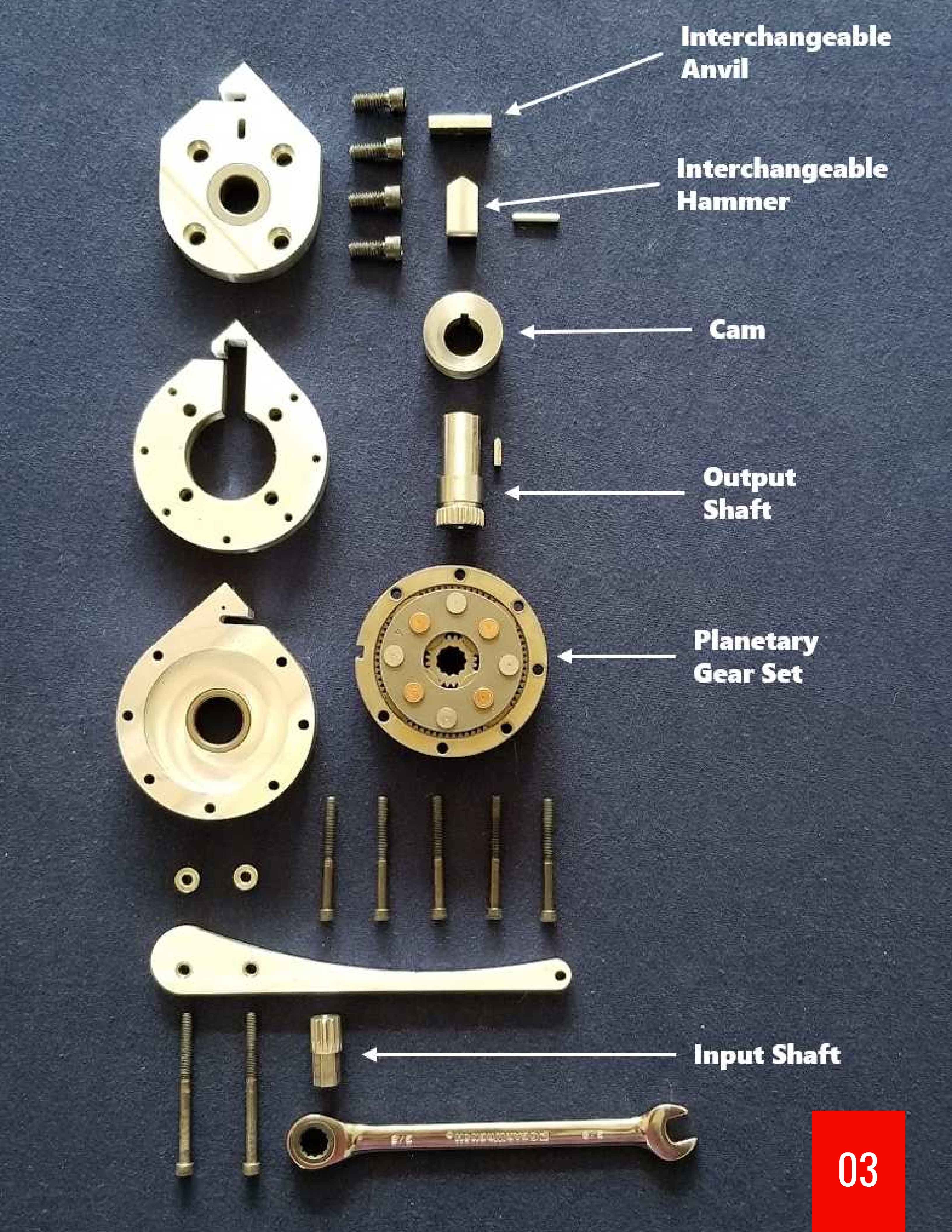
Design Analysis



Exposed cam and 3D printed prototype

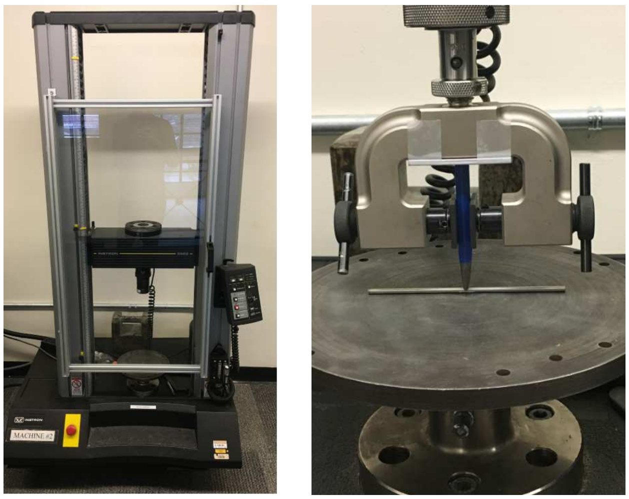
Planetary Gear Set: The input rotation of the handles is immediately transferred to a set of planetary gears which produces a 4:1 torque increase into the shaft that drives the cam. A prototype 3D-printed gearbox can be seen above.

Cam: In order to withstand the high forces involved in crimping the stainless steel tubing, a cam mechanism was utilized to translate the torque from the planetary gear set to a linear force. The crimping action requires a steady motion of the hammer displacing approximately 0.1" into the tubing. The cam surface provides a constant lead to move the hammer along the slot and crush the tubing against the anvil.


Interchangeable
Anvil
Interchangeable
Hammer
Cam
Output
Shaft
Planetary
Gear Set
Input Shaft

Testing Analysis

Instron Machine Testing



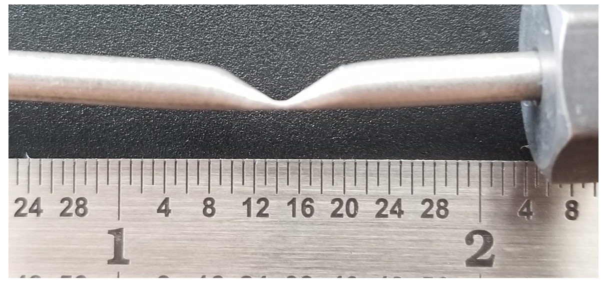
Left: Instron machine used for testing. Right: Early setup utilizing a sharp chisel and flat plate.

Instron Testing: In order to find an optimal crimp geometry for crimping the tubing, multiple crimp geometries were tested using an Instron machine. Based on these results, it was discovered that a more rounded crimping hammer would require too much force while a very sharp hammer would cut the tubing without sealing it.

Crimping Hammer Analysis: Two versions of the crimping hammer were created for additional testing. The tubing crimped by the first hammer did not meet the required leak rate. A possible reason for this high leak rate could be rough surfaces on the inner tubing wall causing small holes where the inner walls of the tubing meet. To limit the impact of those small holes, the tubing needed to be deformed even further. The second crimping hammer version was designed with a sharper tip and operated with further travel. Using this hammer version, the crimped tubing had a smaller final thickness and had an improved leak rate.

Final Results

Tubing Crimped by Tool



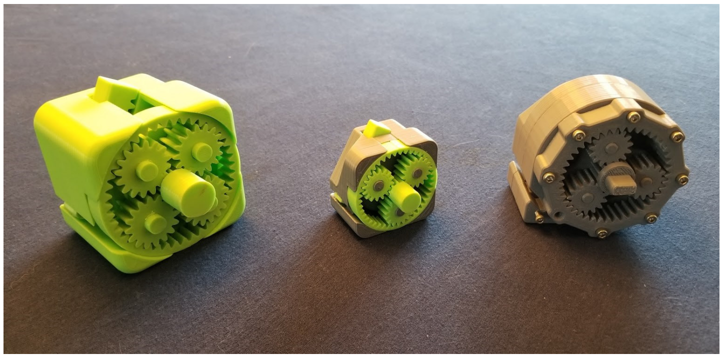
Tubing crimped to 0.017" thickness

Results: The crimp and seal tool is often able to seal the tubing to the specified leak rate of 10^{-4} cc/s. The seal created by the tool has been successful for a few hours while pressurized with air to 100 psi. The housing of the tool had noticeable deformation during the crimp. This deformation never passed the elastic region of the heat treated aluminum, therefore returning to the original geometry after pressure was removed. This tool has the capability to interchange crimping geometries for specified outputs which aided in the final design of the hammer and anvil. The hammer incorporates a sharp profile which is paired with a flat profile anvil.

Exposed internal geometry of a crimp site

Meeting Specifications

Size: The small size constraint of the tool was difficult to meet. The initial size requirement for the tool was a 2” cube. However, off-the-shelf planetary gear sets of this size were unable to handle the torque requirement. Constructing a 2” planetary gear set in-house was constrained by budget and time. Therefore, the project size requirement was increased a 3” cube.

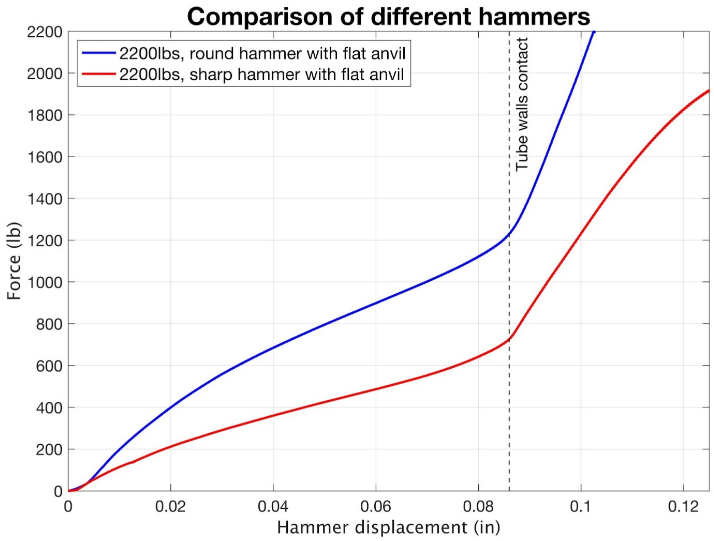


Left to right: An initial design, 2"x2" prototype, full sized prototype.

Tolerances: During the manufacturing phase, tight tolerances had to be kept on areas with sliding interfaces to limit friction and the possibility of binding.

Consistency: Crimping the tubing to a consistent leak rate has been a considerable challenge. Material imperfections or other variability in the tubing as well as potential inconsistencies in the operation of the tool result in sometimes inconsistent leak rates.

Work Hardening: The tubing is composed of a material that is similar to 304 stainless steel. This material work hardens substantially, which causes the required force to displace the tubing to increase dramatically as the tubing is crimped.



Graph showing work hardening of the tubing and lower forces required to crimp with a sharper hammer

Contaminants: Finally, contaminants on the inner surface of the tubing caused unexpected results in early testing and prevented the tubing from sealing. After sufficient cleaning, though, the tubing behaved as expected and was able to be sealed by the tool.

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https://lifephotographie.wordpress.com/2015/04/28/malaysian-fire-and-rescue-department-hazmat-team/