Liquidmetal[®] Alloy in the Miltner Adams MA-6 Hybrid Knife



Industry Sporting Equipment

Challenge

Bring a complex, innovative knife concept to life using the practical and economically sensitive Liquidmetal process.

The first product to be produced in the Manufacturing Center of Excellence in Rancho Santa Margarita, CA is fitting for Liquidmetal Technologies. Codeveloped with a successful world-renown inventor, designer, and engineer, Richard Miltner, the knife is a unique design backed by tradition and manufacturing principles that have made the knife industry so enduring. No matter how novel the idea, there must always be a manufacturing process that physically and economically can manifest it. This case study looks at how the Liquidmetal process brought this product to life, and what it means for the future of complex metal parts manufacturing.

As a new process in the manufacturing space, Liquidmetal technology is poised to offer benefits previously not possible with traditional processes. For traditional processes, increased demand for lower costs with improved precision, quality, and material properties has put many experts in a quandary. Liquidmetal alloy offers engineers the opportunity to take

a step back and rethink their product's needs, breaking away from longestablished manufacturing rules and limitations.



The Liquidmetal Process: A Designers Dream

When Miltner-Adams first contacted the Liquidmetal team, a Hybrid Knife concept was presented. The design concept was based on an eight piece assembly, requiring various complicated and precise machining processes to achieve final part geometries.

The concept of the Hybrid Knife is simple; combine the best elements of a fixed blade and folding knife. The points of emphasis are:

- 1. Solid like a fixed blade knife
- 2. Convenient carry like a folding knife
- 3. Practical for daily use
- 4. Easy to sharpen
- 5. Safe grip
- 6. Hands-free action
- 7. Easy to disassemble

With ease of use as a top priority, the Hybrid Knife will help you accomplish a task in a precarious situation. In comparison to a fixed blade or folding knife, you can get a job done more efficiently, with an emphasis on safety. This in mind, the original concept with eight separate pieces proved to be an uneconomical approach because of its many intricacies. Additionally, once assembled, the knife would be very difficult to disassemble, a major drawback in unpredictable situations.

Working closely with the Liquidmetal team, the finalized design for the Hybrid Knife reduced the total part count from eight to two pieces – the knife blade and the protector.



These final two part geometries would be

extremely costly and difficult to manufacture

using CNC machining, and impossible as net-

Incredible Precision and Innovation

The opening and closing functionality of the Hybrid Knife makes its ease of use seamless. The calculated level of precision required to create a smooth transition between the open and closed position of the blade is a remarkable 0.0005 inches (0.0127mm), or 12.7 microns. Liquidmetal engineers utilized the incredible precision and tolerances available with the Liquidmetal process to meet this specification for every part. Because of Liquidmetal alloy's amorphous structure there is a lack of phase transformation, and very little shrinkage occurs (0.4%). This results in dimensional accuracy and repeatability of $\pm 0.075\%$ of any given part dimension. This repeatable process allows for designs like the Hybrid Knife to become a reality in an economically sensitive way.

In an attempt to fulfill a set of criteria for this novel Hybrid Knife concept, the Liquidmetal engineering team invented a patented interlocking barrel hinge to improve design functionality. What resulted is a design that may be applied to many broader applications. A typical barrel hinge requires multiple components and difficult and time-consuming assembly. Liquidmetal's innovative interlocking barrel hinge, however, enabled a reduced part count, which resulted in fewer molds (lower cost), improved ease of use, and greater functionality of the product.



The Liquidmetal team had the following considerations in the development of the barrel hinge design:

- The two parts must be able to assemble/disassemble without the use of external tools
- The two parts should be locked and secured in the closed position and in the open position
- The knife and protector must remain secure between the closed and open positions

In short, the user would be able to assemble the knife and protector in the unlocked position, secure the protector into a locked closed position, and move the protector into a locked open position.

Given this, the design team implemented these requirements in the search heuristic of the barrel hinge design:

- No more than five tabs (for sufficient individual tab size and hinge robustness)
- Parts should be unlocked and disassemble or assemble at an angle of 0°
- The tabs of the hinge should not align in all other positions
- The parts should be securely & evenly locked for angles 20° to 200°

In order to achieve this design a genetic algorithm was implemented utilizing Python programming. The algorithm took initial/seed solutions and measured their fitness. Fitness is a score that measures how securely fastened the two components are and is a function of how much the tabs overlap in a given position and the locations of the tab overlap around the barrel. The program then randomly takes one of the solutions and varies it in a random way (changing the position of the tab and/or the size of the tabs).

These mutations were then measured for fitness, keeping the better ones and discarding worse mutations. Essentially, what was optimized was the size and position of each tab to always ensure part robustness (i.e., the parts won't pry apart). The algorithm ran for over 14 hours, generating millions of options and testing their fitness, resulting in the physically optimal design used in the Hybrid Knife.

With a two-piece knife, the outcome is an easy to assemble and disassemble design, with no weak points throughout the open and close rotation.

Below is a chart that illustrates the ultimate fitness score of the design chosen. Throughout the rotation of the knife and protector there are no weak points, aside from the open position.



This accomplishment is just one example where the talented Liquidmetal team can assist customers' problem solving efforts.

Incredible Elasticity and Corrosion Resistance

Relying on only a 0.0005" tolerance, the Hybrid Knife made of Liquidmetal has very little margin for error or physical change. Common crystalline materials like stainless steels, titanium, and aluminum have an elasticity of less than 0.70% (as a % of original shape). This means that once the material has been bent beyond that point, it is plastically (or permanently) deformed. Liquidmetal alloy LM105 has an elasticity of 1.80%, as seen in the table below, and will return to its original shape when stressed up to this limit without plastic deformation.



Elasticity (% of Original Shape)

This property allows the Hybrid Knife to maintain its tight tolerance requirements and keep a smooth, consistent feel between both the protector and blade components.

Any other crystalline material, no matter how strong, would eventually plastically deform and create friction between the two parts when subjected to similar bending stresses. Liquidmetal alloy is the perfect material for this design, when there is such a small margin of error in regard to deformation and reduced functionality.

In pursuit of an accurate and relevant quality test, the Liquidmetal team used an FEA (finite element analysis) simulation. Utilizing Solidworks software and implementing measured experimental material properties, the simulation allowed Liquidmetal engineers to get an accurate idea of what the knife's limitations were before testing. A simulated three-point-bend test revealed the areas of highest stress concentration and maximum deflection before failure. From these results, an experimental quality assurance test was developed in which each knife would be subjected to 33% of the theoretical maximum load (~575 Newtons or 130 lbf.). This corresponded to 3.0 mm of displacement at the center of the knife in the three-point-bend test.



Every knife on the market is quality tested to specifications that knives made of traditional materials would deform under, but you are still advised to stress your knife at your own risk.

Rarely outdone by traditional metals, Liquidmetal alloy's as molded corrosion properties are phenomenal. The Liquidmetal team has recently performed specific tests with the Hybrid Knife. Various forms of the Hybrid Knife were tested in a seawater solution at 65C and 90% relative humidity for 30 days; as molded and bead blasted, both with and without the stainless steel clip attached were tested. The knives' masses were measured before and after the test, showing no significant mass loss. Liquidmetal parts, both as molded and bead blasted, passed the immersion corrosion test with flying colors. There was no pitting of rust on these parts at all. On parts with the clip attached, there was a minor amount of rust around the stainless steel clip with the Liquidmetal knife showing no signs of corrosion. Thus, galvanic corrosion did occur but was minimal. The stainless steel clip preferentially corroded since it served as the anode in the galvanic cell; this is advantageous since the stainless steel clip can easily be replaced at a low cost.

There is a large breadth of corrosion data surrounding Liquidmetal alloys, and a recent ongoing study on galvanic corrosion illuminates how resistant the material really is, along with its limits simultaneously. In this "fun" experiment, a piece of Liquidmetal alloy was fastened closely against a fishing knife made of German stainless steel and run through a dishwasher for several months (over 100 cycles).

Illustrated by the image on the next page, before cleaning, the steel knife has corrosion product buildup (rust) on both the contact and non-contact sides, while the piece of Liquidmetal alloy shows no signs of rust on the non-contact side and minor corrosion buildup from the stainless steel knife on the contact side. However, all rust was easily removed during cleaning from both materials. There was no evidence of material deterioration underneath the previously rusty regions, indicating that the Liquidmetal passivation layer remained intact.

All corrosion product was likely just from dissolution of the stainless steel. Also, the corrosion product did not form on the entirety of the stainless steel contact surface, only on a small area. Therefore, although these results tell us that Liquidmetal and stainless steel do create a galvanic cell (with Liquidmetal as the cathode and stainless steel as the anode), it is likely that the anodic indices of each are quite similar leading to a very low corrosion rate. Overall, the minimal amount of galvanic corrosion from Liquidmetal and stainless steel was quite impressive and further confirmed the materials' use in the Hybrid Knife.



Conclusion

When Miltner-Adams initially sought out Liquidmetal Technologies as a manufacturer for their knife design, they were looking for a cutting edge material to coincide with their innovative product. And while there is no question Liquidmetal alloy is an innovative material, what Miltner-Adams received was so much more. A team of seasoned professionals with decades of manufacturing experience, a process that upends traditional expectations, and a final product that breaks down seemingly immovable economic barriers.

In a constant search for an improved material and manufacturing process, every application will see slightly different advantages from Liquidmetal technology. For the Hybrid Knife, the Liquidmetal process reduced the part count from eight to two, drastically simplifying assembly and reducing costs. The process imparted precision and accuracy that would normally come at an extreme cost, if even possible with high end machining operations. And finally, the Hybrid Knife harnesses Liquidmetal alloy's unparalleled combination of high strength and high elasticity with incredible corrosion resistance to make it a truly distinct knife. The Hybrid Knife is a prime example of how Liquidmetal technology can bring a unique set of pivotal properties to many applications, in an economically sensitive way.

Talk to the experts.

Wondering how Liquidmetal alloys might work for your application? We invite you to download our design guide and speak with Liquidmetal scientists and engineers. We are challenging everything you know about metal parts processing. Why not challenge us?

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