# New Fluid Cell Tooling Designs Change the Economics of Aerospace Sheet Metal Parts Production

by Graham Beaumont
Agon Consultancy
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Graham Beaumont is Managing Director of U.K.-based Agon Consultancy, an aerospace supply chain and manufacturing process improvement agency serving tier 1, 2, and 3 aerospace suppliers. A long-time aerospace veteran, Mr. Beaumont has provided design, engineering and project management services for programs including the Eclipse 500™, Airbus A320, A380, and A400M.

**Abstract:** Since the 1960s, aerospace manufacturers, including Boeing, Airbus, Bombardier, Cessna, TAI, Embraer and others, have successfully used fluid cell (or "bladder") presses to precisely form a wide range of aluminum and other sheet metal components. Today, however, a growing number of these parts are being outsourced to supply chain vendors who are unfamiliar with fluid cell pressing, and therefore do not fully comprehend the economic value of investing in this technology.

In this paper, we examine recent advancements, primarily in tooling, that will enable tier 1, 2 and 3 suppliers to profitably incorporate this flexible forming ("Flexforming") process into their operations. Cost reductions (compared to conventional mechanical pressing) can be achieved through single hit pressing of multiple parts with little or no rework, precise forming to tighter tolerances, much lower tool costs, shorter part lead times, and the ability to design and produce complex shapes that would be prohibitively expensive with conventional presses. These same benefits may well persuade OEMs with existing Flexform presses to reconsider their outsourcing strategy and optimize their in-house utilization of this technology.

## Changing dynamics in the aerospace industry

There is little question that the demand for commercial, private, and military aircraft is extremely robust, and will be through the next decade. Aging fleets need replacing, emerging nations have growing needs for modern aviation, the global air cargo business is steadily increasing, and there is a significant acceleration in demand for affordable light jets for corporate and private travel.

With these opportunities come new challenges for airframe manufacturers: new and intensifying global competition, extreme pressure to control costs at all levels, the need for advanced technology to expand capacity and productivity, reduction of labor-intensive processes, and the ever-growing demand for lighter, more fuel efficient aircraft.

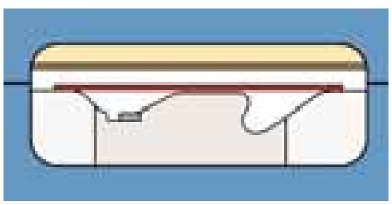
## Supply chain opportunities

As with most major manufacturers in industrialized nations, many aerospace companies are concentrating on core competencies and outsourcing an increasing share of their production, most notably the fabrication of sheet metal components. In some cases, strategic “manufacturing offset” agreements are negotiated with vendors in countries with the potential to purchase aircraft.

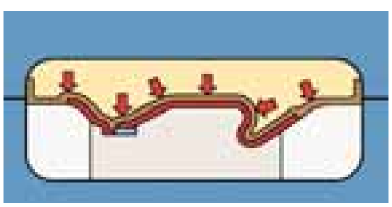
Similarly, many of the original tier 1 suppliers have shifted to more value-added assembly and integration activities, and are contracting parts production to smaller tier 2 and 3 sources. Unfortunately, many of these sources are still using older, lower pressure rubber pad presses, making it difficult to meet the stepped-up quality and delivery demands of the airframe producers.

To be successful, aerospace OEMs and their first tier subcontractors must be assured of low-cost, high-quality, on-time components. By the same token, tier 2 and 3 suppliers must ensure their reliability in these areas to be competitive. The answer to both concerns may well be the recent advancements in Flexforming technology.

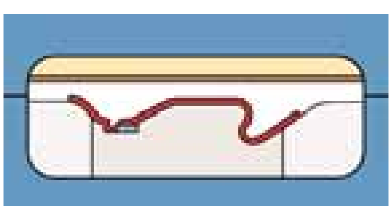
## The fluid cell concept



The blank is positioned on the single rigid tool half and placed without fixing in the forming tray, which can hold multiple parts.



Oil under very high pressure forces the rubber diaphragm to wrap the blank completely and uniformly around the tool half.



After decompression, the finished parts are removed, formed to final net shape with little or no rework required.

Flexforming is basically a simple process. Unlike mechanical and hydraulic presses which use upper and lower forming dies, (often in three pieces), Flexforming uses a single, rigid, shape-defining tool half (also known as a hydroblock or die). A sheet metal blank is placed over this tool and is pressed into shape by a flexible rubber diaphragm under uniform hydrostatic pressures as high as 20,000 psi (140 MPa, an equivalent pressing force of up to 150,000 tons). Multiple tools and blanks are placed freely in large forming trays at each end of the press which shuttle in and out of the central frame containing the pressurized diaphragm. Multiple part sizes, shapes and gauges can be formed in a single one- to three-minute cycle.

Flexforming’s key advantage over mechanical and rubber pad forming methods is the uniform application of very high pressure, forcing the metal evenly into intricate shapes, including undercuts. In some cases, forming, trimming and hole punching can be performed in the same cycle.

## Major advances in tooling design

A "rebirth" of fluid cell processing has taken place basically over the past two years. A great deal has been learned through testing and research about predicting and controlling the behavior of aerospace aluminum alloys and other metals under very high forming pressures. Much of this work has been done in Europe, coordinated by Agon Consultancies and spearheaded by companies including Huskvarna Prototyper AB and Avure Technologies AB (formerly ASEA/ABB) in Sweden, and G. Parkers Engineering in the UK.

An R&D Flexform press at Avure Technologies in Sweden has been instrumental in tooling research.

Studies centered on several materials and a variety of processing characteristics: stretching and elongation under varying pressures, draw ratios, bending radius, strain hardening, elasticity modulus, etc. The result has been a much greater practical understanding of the elastic/plastic thresholds and the tensile and yield strengths of aerospace metals. Among the many findings is the value of introducing tensile stress during the forming process to better control stretching uniformity and springback compensation.

Figure 1. Typical example of tooling used with lower pressure rubber pad presses

This new knowledge has led to significant innovations in the tooling for Flexformed parts. Until now, tool design has been a rather inexact science, often involving the modification of existing rubber pad tooling. Owners of fluid cell presses have either built their own hydroblocks or sought the aid of toolmakers who were experts in mechanical pressing but had little experience with the Flexform process. Through trial and error, a degree of acceptability was achieved, although manual rework of formed parts was often required.

Figure 2. Inappropriate tooling often produces defective parts.

Figure 1 is an example of the tool design which had been a fairly standard configuration in the rubber pad pressing industry, but not suited to fluid cell technology. The part exhibits defects such as material gathering, incorrect flange lengths, and surface "orange peeling". Figure 2 shows a similar but larger tool that produced sufficient circumferential strain to cause an actual tear at the outer edge of the part.

## The new promise of high pressure forming

Figure 3. Redesigned Flexform tool with blank holder

New tooling designs now being developed are dramatically changing the economics of fluid cell parts production. In the example above, a reconfigured tool (Figure 3) has reduced the total processing time for this part by more than 80 percent. These tool design innovations result in far more precision in the control of materials, producing final net size components in one operation with closer tolerances and little or no manual correction.

This new precision, easily incorporated into Catia V5 CAD platforms, provides critical support to the aerospace industry's "part-to-part" manufacturing philosophy. Until now, component assembly time has often been excessive due to misalignment problems caused by failure of the component to meet key assembly tolerance specifications. In addition, parts are generally made with pilot holes, requiring re-drilling prior to attachment. Now, Flexforming can produce components that fit the first time, with full-size holes, speeding assembly operations significantly by eliminating time wasted on manual rework, multiple positioning and re-positioning, and redundant drilling.

These closer tolerance parts can also promote greater use of friction stir welding, a joining process that is two to three times faster than traditional riveting, with a subsequent reduction in the weight of the airframe.

## The Eclipse 500™ program

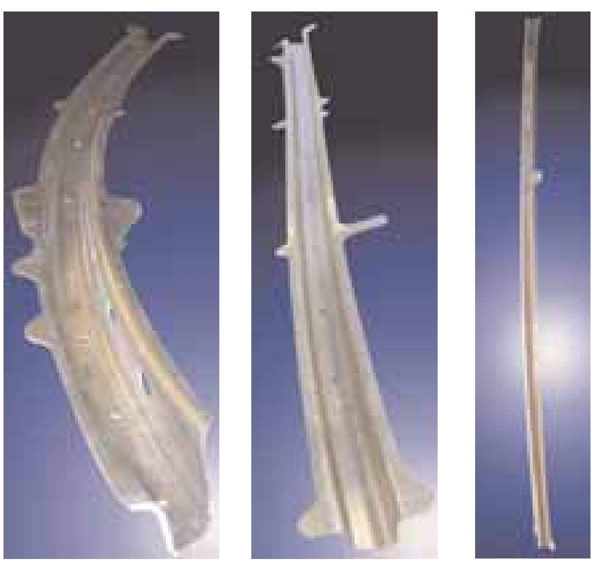


Figure 4. Flexformed aluminum parts for Eclipse

One of the first applications of the new generation of engineered fluid cell tooling has been in support of the very light jet aircraft now being developed by Eclipse Aviation in Albuquerque, New Mexico. The company was founded in 1998 by an entrepreneurial executive who sensed a growing need for affordable private jet travel. The Eclipse 500™ jet, a six-occupant aircraft with low purchase and operating costs, began production in 2006.

Figure 5. Eclipse wing-to-body fairing attachment

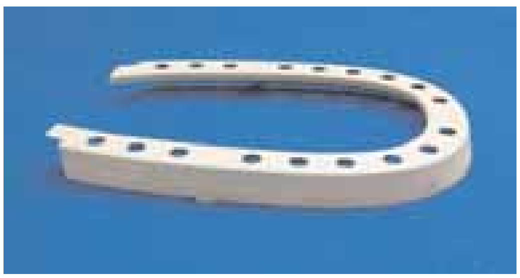


Figure 6. Tail cone attachment ring on empennage

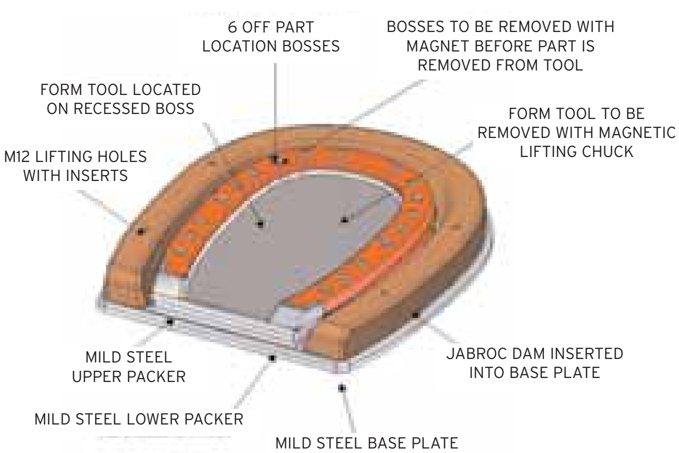





Figure 7

A key factor in meeting the program's cost targets is the adoption of new, highly efficient manufacturing techniques, including Flexforming. Eclipse engineers, working with Agon Consultancy's team of tooling experts, developed and tested an all new tooling suite that would economically produce 106 different aluminum parts (Figure 4). In fact, some of the parts were designed specifically to take full advantage of Flexforming's close tolerance capabilities.

A prime example is Eclipse's re-design of the wing-to-body fairing attachment, or wing root (Figure 5). A number of complex components are involved, with 5-axis shapes and varying cross sections, that would have been extremely costly to manufacture by rubber pad methods, with high levels of production waste. New Flexform tooling, however, enables these parts to be produced to final net shape in one operation, well within strict cost parameters.

The complex part shown in Figure 6 was originally to be produced by rubber pad pressing, but early development trials resulted in a great deal of material gathering, wrinkling, and excessive springback. Many parts had to be scrapped, and those that were not required substantial rework. Total manufacturing time was an unacceptable eight hours per part.

The problem has been resolved with a new Flexform tool (Figure 7) that fully incorporates the new knowledge of the stress/strain behaviors exhibited by modern aerospace aluminum alloys. The part is now Flexformed to a tolerance of ± .030", and, even with a slight amount of final hand dressing, can be produced in less than 30 minutes, a 95 percent reduction in manufacturing time.

## Conclusion

New knowledge of the behavior of aerospace aluminum alloys under high pressure results in new tooling concepts and new opportunities for suppliers to take full advantage of the cost and quality benefits of Flexforming.

For decades, fluid cell pressing has been an established but sub-optimized production process for suppliers to the aerospace industry. The dramatic advances in tooling design discussed above now make Flexforming an even more viable and cost effective technique for an expanding variety of complex formed metal components at all levels of the supply chain.

The development and application of this new tooling expertise has been commissioned and coordinated by Avure Technologies, the world's largest producer of Flexform presses. Further information can be obtained by e-mailing Avure at info@avure.com.

**Sales and Manufacturing:**
Avure Technologies AB
Vasteras, Sweden
Phone: +46 21 327000

**Sales in the Americas:**
Avure Technologies
Columbus, Ohio USA
Phone: +1 614-891-2732

**www.avure.com**