SHOT PEEN FORMING THE WIDEST WING IN THE WORLD

by David F. Cook, President, National Metal Finishing, Inc.

In December of 1984 our company was presented with a very exciting opportunity to quote on the shot peen forming of the Gulfstream IV wing skins.

Unfortunately, we were not the successful bidder and our only competitor with considerably more years in the business than us won the contract award.

A few minor details...like not having a plant available or a wing forming machine to peen the wing skins...must have played some part in the decision.

In March of 1985, being curious, I called AVCO Aerostructures (now Textron Aerostructures) in Nashville, Tennessee, and asked how the program was going. "You want to know the truth", said the buyer, "not very well." "Well, let me have a **shot** at it," I replied. To cut a long story short, I was on a plane to Nashville. After many discussions with Engineering, Manufacturing, Procurement and Quality, I finally convinced them that we could form the 12 foot wide by 45 foot long single upper skin.

To understand the task, you must first understand the wing. Material handling was the first consideration. We had to erect a building 30 feet high to allow one wing to pass over another. Now for the wing design. Although the ultimate in strength to weight ratio allowing the GIV extra fuel carrying capacity, aerodynamic smoothness, power, speed and flying range...it seemed no one had thought about how in the world we were going to form it! The skin had no integral stringers making it lack any specific personality. It seemed that any place you wanted to push it, it would go, the only problem being it returned. How could you shot peen form a skin panel with conventional equipment when you could wrap the panel around a fork-lift truck?

The skin configuration was primarily made up of pockets ranging from .180 thick down to .060, stringer pads from 1/4" to 3/8" and pads on the outer wing tip and aft area up to 1/2" thick. Two cross braces before the dihedral at B/L 145 gave the wing some integrity but did nothing for the forming task.

In basic terms, how do you stretch a wing that has been designed not to be stretched? Understand 3/8" pads, .060 pockets cross braces, the incompatibility of the various metal thickness and their relationship to each other was rather like refereeing soccer, American football and rugby all at the same time!

First things first. After the check fixtures had been installed, we laid the big panel in position, unformed in its flat machined state. This was the beginning of reality at B/L "O" the panel was 14" up in the air! B/L 145 where the dihedral takes place looked O.K. until some bright person decided to pull it down with his hand at B/L "O" and it shot up to 7"!

On most wing forming, it is generally the pattern to stretch form first by peening in a spanwise direction. It didn't take us long to throw that out the window. After too much thought, we decided that due to the nature of this "umbrella-like wing" we must saturation peen the panel first. We must start to give this wing a definite compressive structure. Then and only then can we start the "spanwise stretching".

This is the reason we chose an "air" machine over a "wheel" machine. I can talk all day long on the benefits of air or airless, but this is really the subject of another paper. The only real challenge lay in the design of the machine. Understand, how do you get 16 nozzles to travel across a 12' wide skin without air lines tangling up and shot hoses clogging? Needless to say, it was challenging. With the support of VacuBlast (U.K.) Ltd., we designed a machine that could achieve all this: meter shot and air pressure with computer controlled accuracy.

We insisted upon air for this reason. On such a wing it was essential to have a uniform compressive layer, something that is not always achieved with a wheel. It was essential in a wing of this nature not to produce what I know to be "torsional compressive stress". This type of stress can be as bad as "residual tensile stress" and the two acting together can create more forming problems than you can imagine such as twisting, distortion, lack of repeatability from component to

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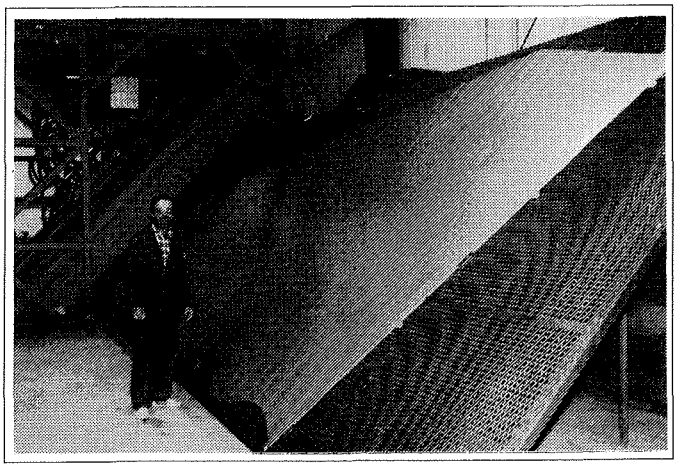
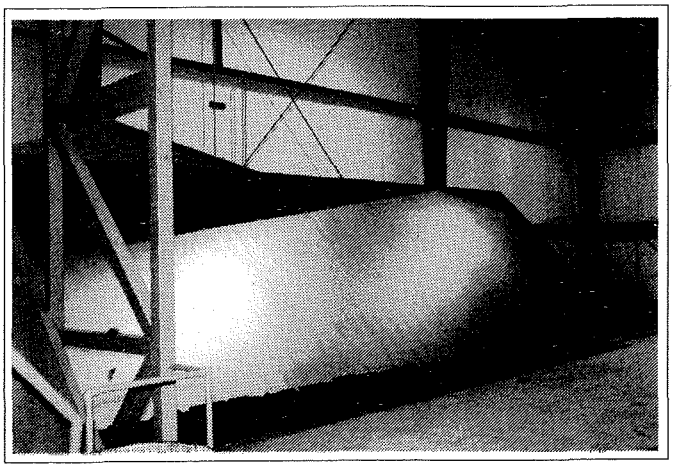


Procedural Monitoring of the Computer Controlled Progress on the 65'x12' Wing Former



The Gulfstream 'IV' Upper Wing

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component. The forming of light structured parts is the study of deep thought and exacting disciplines.

Once having produced a uniform depth of compression on both sides of the wing, we could now go to work on the dihedral at B/L 145.

What is a dihedral? Quite simply, two intersecting planes.

The challenge of this dihedral, or saddleback as quoted in the industry, was its wide radius, larger than the center skin on the 747 and offset so as to give the illusion of an open fan. In simple terms, the front leading edge had to be grown 3/4" with the trailing edge under .100. Some difference!

The method for growing or stretching the leading edge by 3/4" was a frustrating task that took us 6 months to master. The disparity of the pockets .060 to the stringer pads 3/8" meant "bubbling" on the splines would easily occur and it was the result of many weekends, late nights and early mornings to discover how to move the pockets in relation to the stringer pads. The other hurdle to jump was the cross bracing of the wing had no problem with growth within its boundary but would not allow the spanwise growth to progress outside it. The net effect is canning.

In spite of all these obstacles the leading edge of the wing finally dropped to "O" at B/L in the unweighted condition.

Apart from AVCO/Textron's helpful support, we all were elated to form a wing that was threatened with being split through the center at great redesign cost, resulting in probably a less performing airplane.

The only area (which now has been perfected) that we nearly mastered, was a tiny bubble in the center of the wing. On assembly, this would push out and as we perfected our forming method, it became almost non-existent. However, shot peen grows metal...it won't shrink metal. In a single piece skin where a "5" axis contour is being shaped, ideally the center needs to be shrunk and the outer leading and trailing edges stretched.

Textron has now mastered this in their autoclave "by creep forming". The combination of "creep forming" and shot peen forming has now produced the perfect wing that requires virtually no bag weight.

Although not the cheapest way of making airplane wings, the benefits of increased range, aerodynamics, fuel efficiency, and power must open the door to other manufacturers of airplanes to reconsider the possibilities such a demanding dream has brought to reality.

We have now formed nearly 400 of these wings and are proud to have played a role in meeting Textron's goal.

However, if anyone should read this article and have ideas about designing a wing...please get with a shot peen former before making all the decisions.