Peen Forming of Airfoil Shapes for Aircraft Wing Sections

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ABSTRACT

A case study of peen forming of aircraft wing sections is presented. The system utilizes airless blast wheels to accomplish the peen forming. Computerized Numerical Controls are used to monitor and control all machine functions to ensure accuracy, reliability and repeatability of the process.

KEY WORDS

Peen forming; airfoil shapes; longitudinal curvatures; Computerized Numerical Control; compression peening.

Shot peening has been used for many years by the aircraft industry for peen forming of wing sections. Both airfoil shapes (chordal) and longitudinal curvatures (span) of the sections have been formed utilizing this process. The process has proven effective for accurately forming the sections as well as increasing fatigue strength. Resistance to stress corrosion is also enhanced.

However, peen forming machines have historically been operated under manual control. Repetition of the forming operation is totally dependent on the operator's skill in following an established work sequence and manually adjusting the variable controls. Trial and error processing is the norm for obtaining the desired final results. Further, processing a variety of different parts presents a material flow problem. Each set-up becomes time-consuming and tedious. Accumulation of like parts for sequential runs create storage problems.

A recently developed peen forming system, consisting of a Chordal Peening Machine and a Span Peening Machine, has eliminated these problems. This system, which utilizes airless blast wheels, incorporates Computerized Numerical Controls for controlling all of the operating variables, thus ensuring accurate and repeatable system operation.

The Computerized Numerical Control (CNC) for this peen forming system consists of an industrial processor, cathode ray tube, manual keyboard, control panel, a tape reader, a magnetic disk, input/output racks and power supplies. The CNC accepts preprogrammed data and automatically controls and monitors the various functions that are required to develop a given part. These variable functions include proper attitude of airless blast wheels, proper positioning of blast wheels, blast wheel speed, shot flow rate, and work travel rate through the machine.

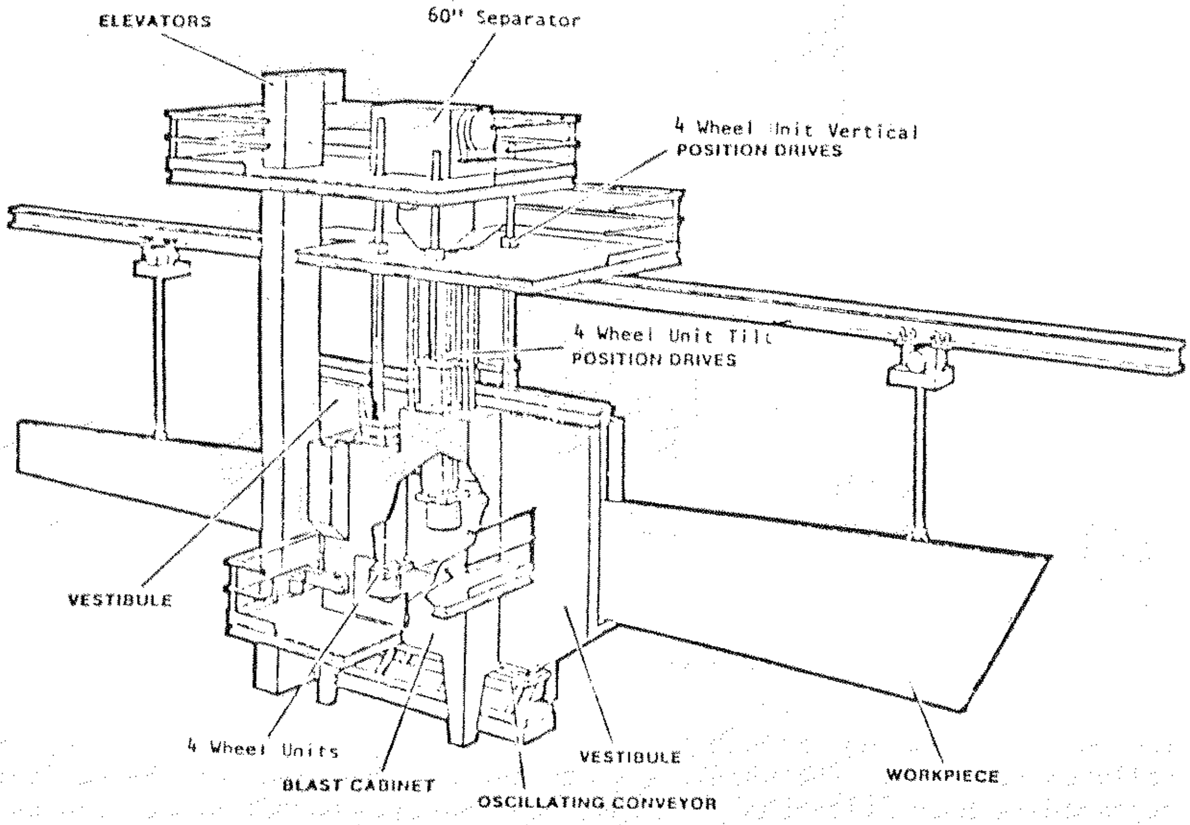
The user had previously developed formulas to determine the shot intensity required to produce a given contour or compound contour in order to obtain the desired shape from a flat section. This information was translated into the machine variables required to produce the finished contour. Conventional control devices are used on the machine for the DC wheel motor speed control and the DC Servo motors. Standard electro-mechanical hardware completes the control package. The shot flow is continuously monitored and adjusted to a set point by two coils located in tandem below the abrasive control valve. Permanent magnets, integral to the abrasive control valve, prohibit the flow of shot. Applying voltage to a coil in the control valve decreases the magnetic strength permitting shot to flow. By combining the monitor coils and the control valve coil in a closed loop system, we obtain and maintain the desired shot flow rates.

Programs, once developed, can be duplicated for each successive unique part. Repeatability, uniformity and accuracy are assured.

The system is operating in accordance with the following application parameters:

Maximum Skin Size	9'-0" wide x 110'-0" long (274 cm x 3352 cm)
Maximum Production Rate	Average skin 900" (2286 cm) long to be processed in not more than 77 minutes.
Chordal Machine Shot	S-460 and S-230 with exchange of shot under operator control.
Spanwise Machine Shot	.25" (3mm) diameter balls and S-460 with exchange of shot under operator control.
Intensities	.25" (3mm) shot - 2C to 20C S-460 - 6 A to 34 A S-230 - 2 A to 14 A
Coverage	100% with .125" (3mm) shot, 60% with S-460, 100% with S-230

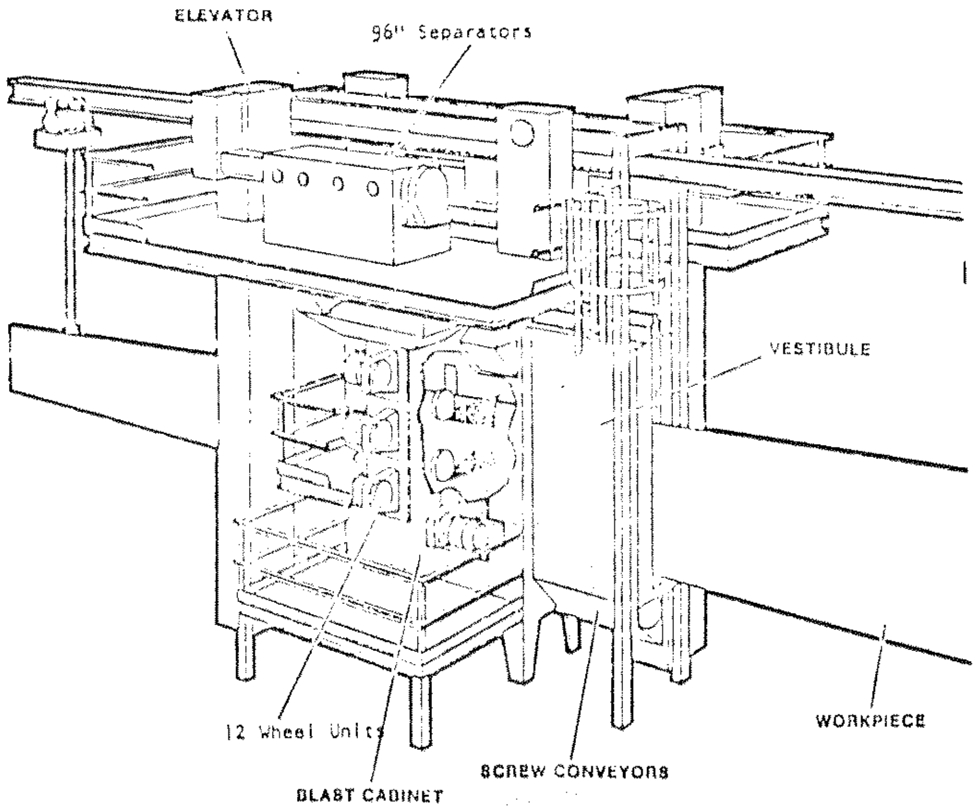
In operation, the wing skin is first processed in the Span Peen Forming Machine. This unit has four 20 HP wheels, each driven by a variable speed motor at 200 to 2000 RPM. The wheels are mounted two on each side of the machine. The wheels are pivot mounted to provide angular adjustment and each unit is mounted on a separate vertically traveling carriage to provide vertical position adjustment.



4-Wheel Peen Forming Machine

The work passes through the machine hanging vertically on carriers. With the work hanging in a vertical manner, there is no shot build-up on the workpiece ensuring consistent peen forming. The blast wheels generate peening strips 3" (76 mm wide) and successive passes are made to peen sequentially as required.

After completion of the span peening, the work is then passed through the Chordal Peen Forming Machine. This unit has twelve 20 HP wheels, each driven by a variable speed motor giving 200 to 2000 RPM. The wheels are mounted six on each cabinet side wall in fixed positions and are arranged to blast at 90° to the direction of work travel.



12-Wheel Peen Forming Machine

The work is conveyed through the machine in the same manner, hanging vertically on carriers. The wheels are located on both sides of the cabinet to accommodate both left-hand and right-hand parts. Normal processing calls for operating wheels on only one side of the work during chordal peening. Wheels on both sides of the machine permit processing the opposite hand parts. The machine needs only be programmed for one hand wing skin. The CNC is equipped with mirror imaging to provide proper coverage for the opposite hand skins. The number of wheels operating at any one time is determined by the width (vertical dimension as conveyed) of the wing skin.

After peen forming is completed, the work is sent to the checking fixture. A series of contour headers spaced approximately 24" (610 mm) apart running the length of the wing section is used to check the spanwise and chordal curvature.

Weights may be applied at header points on a wing panel to further deflect the part if it is out of tolerance at a particular point. A limit of three pounds (1.4 kilograms) per inch (25 mm) is established with a maximum total weight of 100 pounds (45 kilograms) per header.

After the wing skin has been suitably formed, the skin is then transported to a wing skin sanding machine. The skin is sanded for aerodynamic and esthetic purposes in those areas where the surface is roughened by the shot peening operation.

After sanding, the wing skin is returned to the Chordal Peen Forming Machine for compression peening of all skin surfaces utilizing S-230 shot. In this operation, wheels on both sides of the machine are utilized to accomplish the required peening.

After compression peening, a final contour check is made. The skin is then delivered to the tank line for chemical processing followed by painting and baking of a coating of corrosion inhibiting primer. The wing skin is then ready for assembly.

Daily checks are made of the shot intensity in both machines. Almen strips are used as a control check. Specified arc heights at specified wheel speeds and shot flow rates in a specified time must be met in order for that day's work to commence.

Use of this system takes the guesswork out of the art. Known mathematical equations, precise and repetitive control through the use of CNC and custom designed control devices and reliable equipment operation serve to make an exact science of peen forming.