Integrally Stiffened Wing Panels Formed by Shot Peening Method

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THIS INTEGRALLY stiffened wing panel has been cut at Lockheed Aircraft Corp.'s Burbank plant from a solid slab of metal. This type of structure results in an improved dead-load to pay-load weight ratio.

Integrally Stiffened Wing Panels Formed by Shot Peening Method

By TED C. SIMMONS

METAL FORMING

SHOT peening, a mechanical cold working process involving the bombardment of metal with tiny pellets, is customarily thought of and ordinarily applied as a method of improving fatigue life characteristics of metal parts. Less known is its utility as a method of forming.

The aircraft industry, faced recently with a tough forming problem in the development of revolutionary integrally stiffened ("I.S.") wing panels, explored a number of means. But not until it hit upon the idea of using shot peening was it on the road to a practical solution. Actually, shot peening not only answered the problem satisfactorily, but gave certain supplemental benefits.

Use of shot peening in forming may appear novel, but it is actually a technique of long standing. In its most rudimentary form—the use of a ball peen hammer—it is clearly an ancient art. The new application, considering its importance, heavily underscores its utility as a forming method. The stellar role shot peening has played in recent years in extending the life of metal parts which are subject to fatigue, shock, impact, or stress corrosion has tended to obscure this forming phase of the method's usefulness.

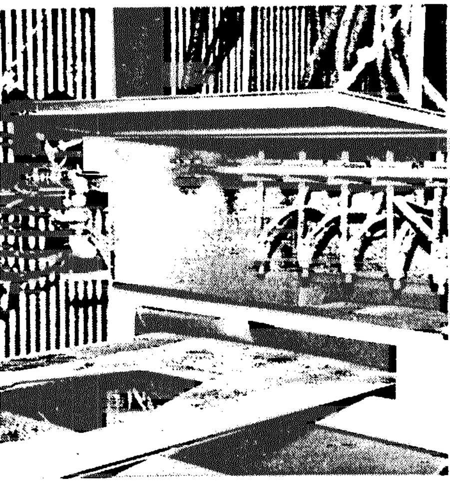
Shot peening is widely known, for example, for its part in the perfection of the modern automobile valve spring. In the '20s premature failure of these springs was a commonplace matter. Today such failure is rare indeed. Through the years there have been certain metallurgical improvements in the springs, to be sure, but it was not until these were coupled with shot peening that the problem was actually solved.

Although peen-forming is a technique of long standing the new application presented many problems not previously encountered. From the standpoint of size alone the wing panels represented the largest single pieces ever handled.

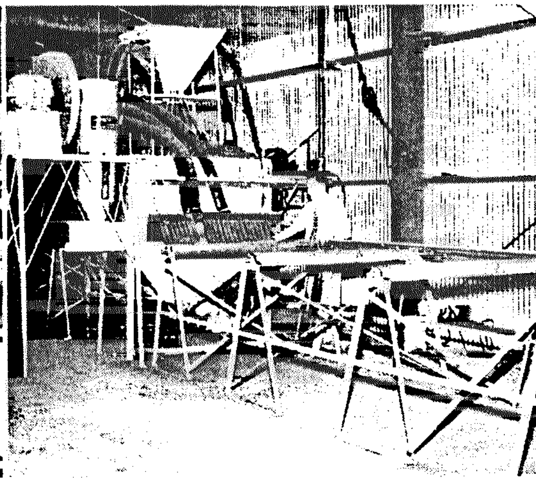
"I.S." panels now being formed by this method are unique in that the skin and the stiffening members which create the structural surfaces are of a single piece. These panels represent a tremendous simplification over the usual multi-piece skin-and-stiffener structure, yet are in themselves no simple thing. Their complex form is achieved by "sculpturing" them out of a huge solid slab of metal on giant skin mills.

In machining these surface panels from thick aluminum alloy plate, 80% to 95% of the original stock is cut away in chips and trim. At the completion of this operation the panels present a flat outer surface which remains to be curved to meet aerodynamic requirements. It is in attaining this form that shot peening comes into play.

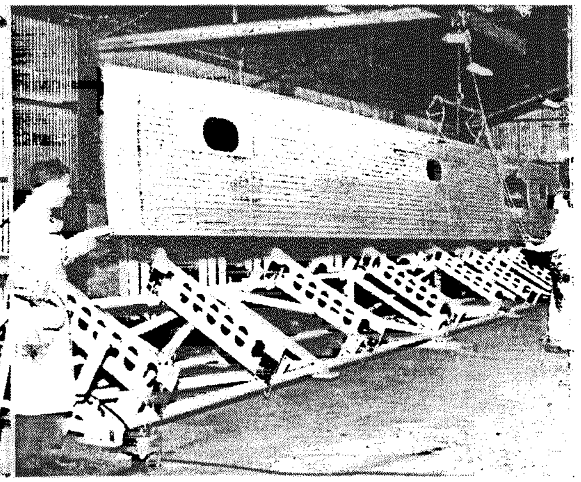
The fact that the panels are of 75ST6 aluminum alloy rules out consideration



A WING PANEL is here passing through forming cabinet, the door of which has been opened to show the nozzles through which the fine round shot is emitted. Controls are at left.



AFTER the shot peening, the "I. S." wing panels emerge slowly from the cabinet to the conveyor at the back of the machine. Note the vacuum system for recovery of the spent shot.



WHEN forming is completed, the panels are moved by an overhead crane so that they can be lowered onto the templates of a checking fixture, which are different for each type of panel.

panels with as much as a 1-in. arc in 32 ft have been aligned in this manner.

The entrance into the new field of "I.S." wing panel forming and a growing need for conventional shot peening in the West recently made it necessary for the 6-yr-old Metal Improvement Co. to move to a 9000-sq ft plant.

While the work on the new integrally stiffened wing panels presents the most colorful aspect of current production at the plant, by far the largest volume is within the customary sphere of shot peening—increasing the fatigue life of metal parts. Tests have shown that an increase in fatigue life up to several thousand per cent may be achieved.

Items ordinarily handled are springs of all sizes, including coil, leaf, and torsion bars; shafts and welded joints; and gears, which are peened principally to prevent cracks from forming in the root fillet. However, it has been found that gear wear can be reduced through the process, since the fine indentations left by the shot act as oil reservoirs, thus giving a better lubricated part.

Operating Principles

While the plant's shot peening machines vary considerably in the kind of work handled, the operating principles of each is similar to forming the "I.S." wing panels. Each expels fine round uniformly-sized shot through nozzles under controlled air pressure within a closed chamber. The shot is automatically fed back to a hopper for re-use after any broken shot is rejected in a separator.

The sizes of shot maintained in stock vary from .013 in. to .046 in. nominal diameter. Each machine has its own regulator and Fisher governor, permitting it to operate at exact pressures up to 125 psi.

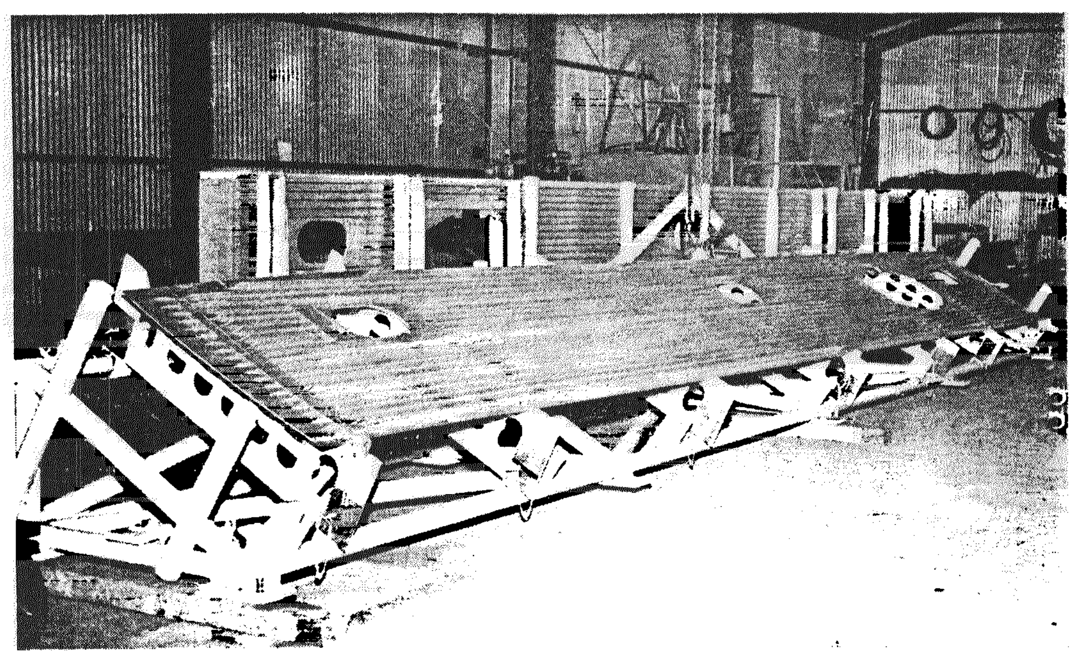
In addition to air pressure, five other important variables are at the operator's command—shot size, shot feed, nozzle size, distance of nozzle from work, and time of exposure. The company has recently added flame hardening as a corollary of its shot peening service.

To return to the forming of the "I.S." wing panels, while this phase of shot peening currently represents but a minor activity in the company's work, the potentialities of it appear great.

The development of the panels is considered one of the hottest items in aircraft manufacturing circles since they are capable of carrying a greater load while weighing less than the usual multipiece skin-and-stiffener structure. Further, they represent a simplification of the manufacturing process. Through this type of fabrication 1500 separate parts and 5000 rivets are eliminated in a 32-ft wing section.

The use of shot peening in forming this newest type of structure for the aircraft industry serves to point up the technique's growing value as an industrial tool.

THE FORMED PANEL is now resting on the checking fixture so that accuracy of the slight curvature of the panel can be inspected.



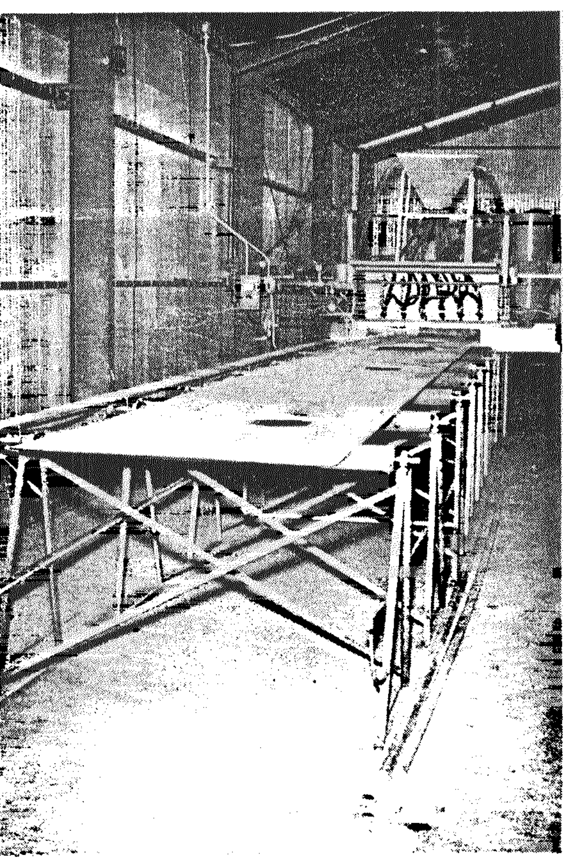
of ordinary cold forming methods. While hot forming might appear a logical answer, the huge bulk of the wing panels (the largest measures 32 ft long by 46 in. wide) makes this impractical. Lockheed Aircraft Corp. engineers, who are responsible for the development of integrally stiffened panels, had first favored this method but later consideration of the difficulties in handling, plus the amount of tooling required in the process, caused them to reject it.

Calculations showed that by the use of conventional cold forming methods a surface tension condition in excess of 20,000 psi could be expected. This is a highly undesirable condition because of stress corrosion characteristics.

It was at this juncture that James Borger, Lockheed production methods engineer, and his associates on the project hit upon the idea that the stress condition caused by cold forming could be relieved by shot peening the tensile side of the panel.

Experimentation along this line got underway. The work was done at the Metal Improvement Co. in Los Angeles. Typical sections of the wing panel were shot peened and it was found that the technique permitted them to achieve considerable curvature. However, to attain a uniform curvature in a section which might run from a thickness of .500 in. to .050 in. within the space of two inches brought up further difficult problems.

ONE OF THE 32-ft long wing sections is on the conveyor table about to enter the shot peening cabinet to be formed. This 75-ft long wing-panel-forming machine was specially built by the Metal Improvement Co. to handle this particular forming job.



Importance of Peening Intensity

The solution lay with peening intensity. Greater pressures were required on thick sections, and vice versa. This required a highly flexible control over shot intensities and a skilled machine operator. Through trial and error methods the proper intensities were found. With this knowledge a skilled operator could form a given part in a single pass through the shot peening machine. Further, if the part was over-formed because of too high an intensity, it could be peened on the opposite side to reduce curvature.

The most important single fact to come out of the experiments was that the panels could be formed to desired curvature by the use of shot peening alone. Rather than playing a mere secondary role — the relieving of a stress condition set up by ordinary cold forming (the role first contemplated)—shot peening supplied the entire answer to the forming problem. Prior to these experiments engineers were skeptical of the ability of shot peening to bend the panels to the desired degree.

The curvature specified is a radius on the inboard end of the wing panel of about 300 in. and on the outboard end of approximately 180 in. In this method of forming, curvature results from the fact that a compression layer is created on the surface bombarded. This compression lengthens that surface and because it has become longer than the under surface, curvature takes place.

Supplemental Benefits

There are supplemental benefits, as suggested above, derived from peen-forming—the term which Fred K. Landecker of Metal Improvement Co. uses for this technique—beyond its simple ability to form the part to requirements. The process sets up a high residual compressive stress in the upper surface of the panel through the impact of the shot on that plane. The particular value of such a compressive layer is that fatigue fractures cannot originate and cracks cannot propagate in compressively stressed material.

One of the particular niceties of the process is that a beneficial compressive stress is also set up in the under surface of the panel during the forming. This is not a direct result of shot impact, as only the upper surface is bombarded (except in the case of over-forming), but is a product of the bending action itself.

To handle the 32-ft wing sections the Metal Improvement Co. engineered and built its own special machines 75 ft in length, since none existed on the commercial market. The project—a rush job —took but 2½ weeks due to the fact that the company had considerable past experience in the construction of shot peening machines—again because the machines required were not on the market.

Peen-forming Equipment

The major elements of the "I.S." wing-panel-forming apparatus consist of a shot peening "cabinet," which houses the actual peen-forming machine, and two long conveyor tables on either side. In operation, the wing section moves slowly through the cabinet from one conveyor to the other. As it passes through the enclosure, it is pelted with a rain of fine shot emitted from nozzles.

The shot is expelled by means of air pressure. The intensity of the bombardment varies in relation to the configuration desired and the thickness of the part. As noted, the intensity is a closely regulated factor.

A novel type of auxiliary equipment on the shot peening machine is a vacuum system supplied by Sherman Vacuum Equipment Co., which is used for recovery of shot that remains on the wing panel as it emerges from the cabinet.

No Tooling Needed

A unique feature of peen-forming is that no tooling is required. There is a tendency for most persons to visualize the "I.S." wing panels as being formed to a block or fixture, but this is not the case. The only pieces of equipment required on this score are checking templates. Production runs are permitted with the plant's present equipment.

Another job accomplished with shot peening in conjunction with the wing panel program is the straightening of panels which are warped in the plane of the skin, due to residual stress in the plate stock. This occurs chiefly in panels with long narrow sections. The straightening technique consists simply of peening a narrow path on the inner and outer surface along the concave edge. Skin