Shot peen-forming of NC-machined parts with integrated stringers using large balls

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Introduction

In order to achieve savings in the manufacturing costs and weight, integrated parts are extensively used today during the manufacture of aerospace components.
For this purpose, stringers, ribs, doublers and skins are integrated into a milled part, whereas with the traditional differential construction method these individual parts had to be riveted together. The integrated parts must, in many cases, be formed to a design-related contour.

In this lecture the shot peen-forming using large balls for a stringer-reinforced fuselage skin of the Airbus A310 and a stringer-reinforced frame-segment of the watertank of the 1st stage of the Ariane 4 will be presented. The fuselage skin of the Airbus A310 is a dynamic-loaded part, whereas the frame-segment is a static, highly-stressed component.

The influence of the forming procedure on the material characteristics will be indicated with the aid of qualification tests. Here the problems of internal stress, corrosion and fatigue behaviour will be entered into.

Shot peen-forming of a stringer-reinforced fuselage skin

At the start of the A310 project we received an order for forming a stringer-reinforced integral part, the so-called "skinfield" or side panel (Fig. 1). This part is located on the fuselage behind the emergency exit frame, and terminates on the upperside of the wing. The dimensions of the part were 1300 x 4300 mm and the material was 7075 T7351.

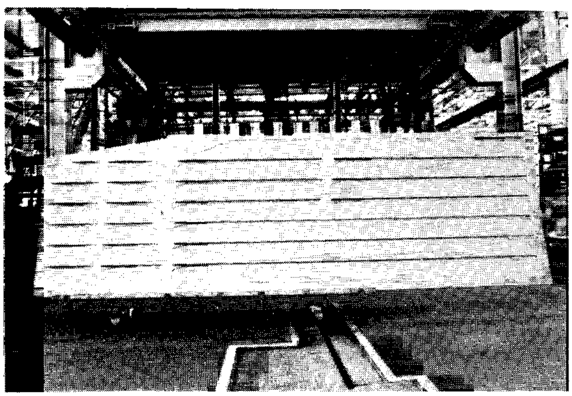


Fig. 1:
Side panel of A 310

The skin field presented very specific forming problems. The part concerned had wall thicknesses between 2,5 and 8 mm and uninterrupted stringers, i.e. it had different resistance moments. The main problem regarding the forming was that an area of the side panel remained flat, which inevitably resulted in a break in the curve.

We were faced with the alternative of either using the qualified bend-forming procedure, which is very costly as a result of the extensive realignment work required, or developing a new and more economical procedure.
As the wing panels of the A300 had been formed using the shot peen-forming procedure for quite some time, we concentrated our efforts on this procedure.

A comparison of the two procedures resulted in substantial advantages in favour of the shot peen-forming procedure:

- residual compressive stress on both surfaces
- no over-bending required
- forming parameters can be defined more exactly
- forming parameters can be reproduced much better
- less realignment required
- lower system costs
- lower manufacturing costs.

The comparison also resulted in a few disadvantages:

- the tensile internal stress in cross-section is higher
- the surface is affected (R_a, R_t)
- spherical deformation.

Whether the tensile internal stress affects the material characteristics, had to be indicated by the qualification programme. According to examinations carried out by the MBB company, ball indentations on an aircraft's external skin to a depth of 0,05 mm are not harmful regarding the aerodynamics. The objective was therefore to reduce this value, and also to find procedure-technical measures to prevent the spherical deformation.

The forming effect with shot-peening is that the blasted side of a sheet is elongated as a result of the plastic deformation, whereby the sheet is curved against the flow blast. The radius, which takes place during the blasting, is affected by the blasting parameters.

Further influences result from system-specific characteristics. We decided in favour of a suction blasting system. The main reasons for this decision were that

- balls with large diameters (up to 8 mm) can be used without problems
- the dispersion angle is small
- the blasting-medium dosage can be easily reproduced.

Our objective was to form the skin field as close as possible to the final contour using only shot-peening, in order to reduce the amount of realignment work to a minimum. In addition the blasted surface should, if possible, only indicate flat ball indentations. This resulted in forming with 6,5 mm diameter balls.

During the forming of the first panels, an undesired curvature occurred lateral to the forming direction, which resulted from the axial-symmetric deformation-distribution of the ball indentation.

In order to avoid this curvature, tests were carried out using elastic pre-stressing in the direction of the curvature (Fig. 2). The result was that with a constant forming radius with increasing pre-stressing, the undesired curvature in the lateral direction and the required blasting medium quantity per surface unit were reduced.

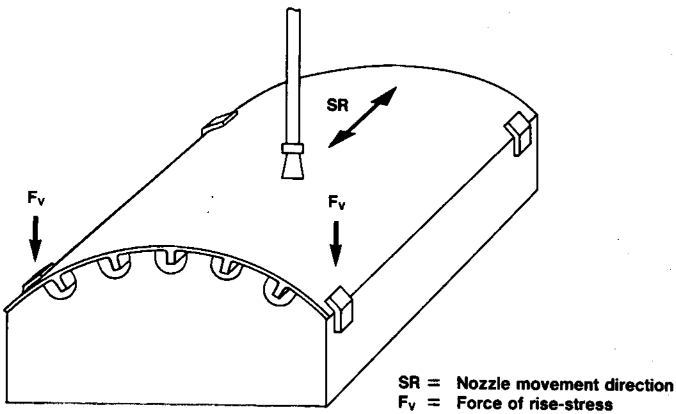


Fig. 2

Having gained this knowledge, we then started the series production. After a relatively short period of time, we were able to bring the panels almost to the final contour only using shot peen-forming, whereby the additional objective of only having to carry out an absolute minimum of realignment work was also achieved.

In comparison with the bend-forming procedure, we were able to achieve a reduction in the working time of approx. 30%.

Shot peen-forming of a stringer-reinforced frame-segment

During the development of the ARIANE 4 we were entrusted with the building of the structure watertank for the 1. stage. The tank comprises a cylinder and a composite dome. The tank is located between the UDMH tank and the N_2O_4 tank approximately in the centre of the 1. stage. The cylindrical tank unit is reinforced with stringers and is built up from eight frame-segments, each 1500 x 670 mm (Fig. 3). The material used is also 3.4364 T7351 or equivalent 7075 T7351.

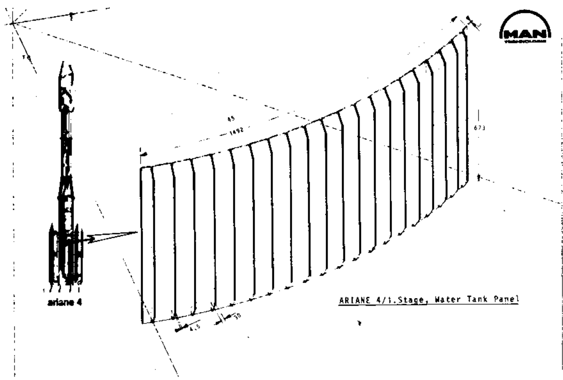


Fig. 3: Water tank panel
ARIANE 4/1. Stage

Contrary to the side panels for the Airbus, for the cylinder segments there was no economical alternative to shot peen-forming.

The significant differences in the forming, as compared with the skin fields, are as follows:

- the stringers are located on the side to be blasted
- certain frame-segments have thickness areas in the skins of up to 25 mm as compared with the skin thickness of 3 mm.

Therefore a different method of approach is required from that used for the side panels of the A310.

Prior to the shot peen-forming, the thickness areas are brought to the final contour by bending in a die (.R = 1900 mm).

The stringer upper edges are covered with masking tape, so that the transition from stringer to skin remains unaffected (Fig. 4). The part is elastic pre-stressed over the grid-gauge. The surface is blasted in line-sweeps, whereby the nozzle is always positioned over the centre of the stringers, until the skin of the part rests on the grid-gauge free of tension. The grid-gauge corresponds to the final radius, and also serves for the final acceptance of the part.

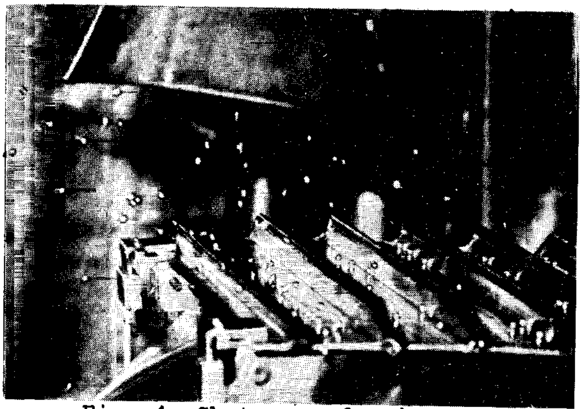


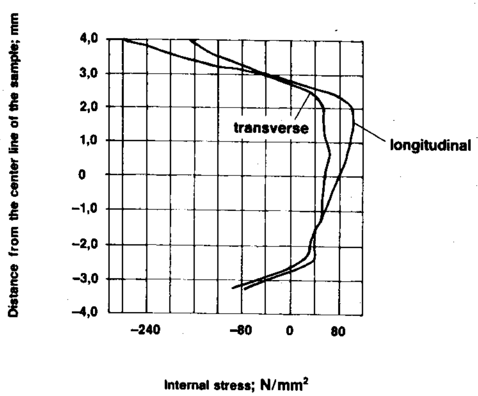
Fig. 4: Shot peen-forming of water tank panel

Decisive was, in addition to the cost advantages, that the forming procedure causes no significant reduction in the static strength characteristics of the material. The stress analysis was initially only carried out theoretically and then achieved in the qualification tests of the tank structure.

Influence of shot peen forming on the material characteristics

Regarding the characteristics, our initial interest was the flow of the internal stress which takes place in the part. The measurements were carried out with the bending deflexion method. Fig. 5 shows the internal stress flow in the skin field of the A310 in the curvature direction and in the lateral direction. The residual compressive stress on the surfaces in the curvature direction are 280 N/mm2 and in the lateral direction 180 N/mm2.

Fig. 5: Peenformed surface = chemical milled surface



Internal stresses in a machined part of Airbus A310; peenformed with rise-stress; Material 7075-T7351

The question whether the material characteristics are affected by these internals stresses, was examined in a qualification programme which contained the following tests on plate material 7075 T7351:

- topography of the blasted surface
- stress corrosion
- fatigue strength on perforated shouldered specimens
- fatigue strength on part-similar test pieces, configuration such as longitudinal and lateral seams of the skin field on the joints to the adjacent fields
- service life analysis with a skin field in the fatigue test structure.

The examination of the topography of the blasted surfaces resulted in a maximum ball indentation depth of 0,05 mm. Therefore the requirement, that the aerodynamic behaviour of the surface is not changed, was fulfilled.

The SCC (Stress Crack Corrosion) tests were carried out with test pieces (DIN 50908), which were loaded with 75% of the yield point (29,3 hbar) and tested for 1000 hours using the salt spray test method. None of the test pieces indicated cracks.

For the fatigue strength tests, perforated shouldered-specimens with four different treatments were selected:

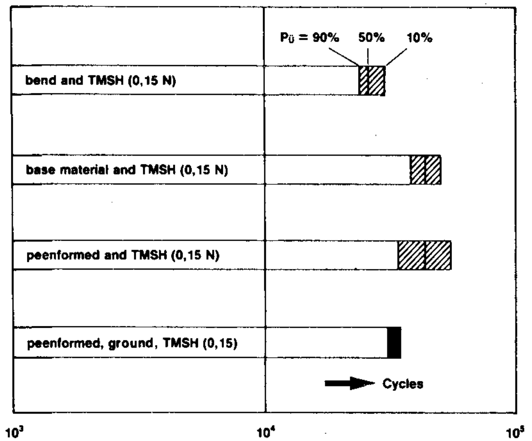
- bend-formed
- untreated
- shot peen-formed
- shot peen-formed and ground.

All of the test pieces were finally wet blasted with glass beads (diameter 250 to 400 µm) and then provided with surface protection (anodized coating and primer).

The test pieces were tested under a fluctuating tensile load.

The results are shown in Fig. 6, whereby the survival probability is indicated as a function of the load change which was endured. It is recognizable, that the test pieces formed by shotpeening have a higher survival probability than those which were formed by bending. They are at the same level as the untreated, however, with a higher dispersion. After grinding off the shotpeened surface, the survival probability and the dispersion are reduced.

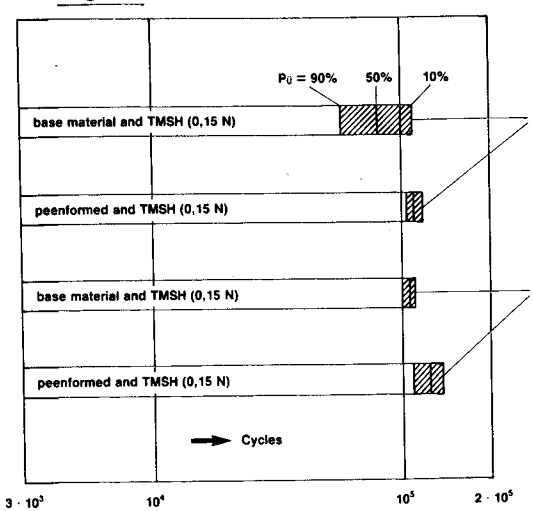
Fig. 6: Survival probability $P_Ü$ of drilled Samples



Material 7075-T7351;
plate; thickness 8 mm
P_O = 5 kN;
P_U = 3,75 kN;
Frequency = 4 Hz constant
TMSH = shotpeening with glass beads

For the analysis of the fatigue strength of the rivet connections to the adjacent structure parts, rivet test pieces were made with a configuration as they actually occur on the longitudinal and lateral seams of the skin field on the joints to the adjacent components of the A310 fuselage. A comparison was made between test pieces whose skin field side was in one case untreated, and in the other case formed by shot-peening. In both cases the test pieces were wet blasted with glass beads, chromic acid anodized and provided with primer.

Fig. 7: Survival probability $P_Ü$ longitudinal and transverse riveted joint



longitudinal riveted joint

A 010 204 83/C
P_O = 50 kN
P_U = 5 kN
Frequency = 5 Hz constant

transverse riveted joint

A 010 204 84/C
P_O = 103 kN
P_U = 10 kN
Frequency = 5 Hz constant
TMSH = shotpeening with glass beads

These test pieces were also tested in the fluctuating tensile load range.
The results are compiled in Fig. 7. Not only with the longitudinal but also with the lateral seam test pieces, the survival probability of the shot peen-formed test pieces is slightly higher than the untreated test pieces.

With these results, it was confirmed that the characteristics of the material 7075 T7351 are not deteriorated by shot peen-forming.