¼ TANK BULKHEAD SEGMENT FOR THE EUROPEAN ARIANE 5

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ABSTRACT

The Institute for Metal Forming of the RWTH Aachen has been involved in shot peen forming since the nineteen-seventies. Numerous developments have been carried out to date in close co-operation with the aerospace industry.
In order to guarantee a high standard of manufacturing, a 7-axis CNC-controlled shot peening plant was put into operation in the institute at the beginning of 1993. The optoelectronic measurement of the shot velocity and measurement of the contours of the components to be peened with a laser system, in conjunction with the on-line recording of the peening parameters, enables a controlled shot peen forming to within very narrow manufacturing tolerances.
In Autumn, 1995, the forming of a ¼ tank bulkhead segment (length 4,500 mm, width 2,500 mm with a radius of 3,004 mm) for the cryogenic main stage H150 of the European Ariane 5 rocket was successfully proven in a joint feasibility study.

KEYWORDS

Controlled shot peening, on-line measurement and recording of peening parameters, shot velocity, 3D laser contour measurement, virtual masking, cost reduction, form-optimising artificial ageing

HISTORY

The Institute for Metal Forming of the RWTH Aachen has been involved in shot peen forming since 1970 (1). Manufacturing strategies for the side shells of the A310 Airbus, the tank segments of the Ariane 4 and the spherically curved tank

domes of the new Ariane 5 have been developed from their prototypes through to industrial-scale production in co-operation with the aerospace industry (2-4).
The Ariane 5 is the successor of the European Ariane 4 booster rocket. The cryogenic main stage H150 of the Ariane 5 is cylindrical and is closed at both ends by two hemispherical bulkheads. A further hemispherical bulkhead inside the main stage divides this into two chambers, see Fig. 1. Up to now, each bulkhead has been made of 8 segments which have been given their spherically curved form by shot peening, see Fig. 2, and which, when welded together, make up a tank bulkhead.
In order to reduce the number of welding operations, the production of ¼ tank bulkhead segments is planned for the medium term.
In a joint project involving the Kugelstrahlzentrum Aachen GmbH, Daimler-Benz Aerospace AG and the RWTH Aachen, a first ¼ segment was formed on the NC-controlled shot peening plant at the institute for Metal Forming in the Autumn of 1995.

LASER MEASUREMENT AND PEENING STRATEGY

Since raw material was unavailable in the size required for the ¼ segment, two 1/8 segments were welded together following minor modifications.
A concave pretensioning device was constructed for forming onto which the ¼ segment was fixed with clamping levers. The 35° arrangement of the pretensioning device in the peening plant was intended to prevent shot collecting on the component during peening and thus preventing forming.
In order to obtain reference points with respect to the mass per unit area which had to be applied, the component clamped in the pretensioning device was initially measured with a laser fixed to the shot nozzle. The deviation between the measured actual component contour, which roughly corresponded to a shape somewhere between the envelope of a cone and a calotte shell, and the desired contour (calotte shell with a radius of 3,004 mm), was taken as a basis for the peening strategy to be employed, see Fig. 3. In the areas of greater deviation, the mass per unit area to be applied is correspondingly higher than in the areas with a small deviation.
The peening pressure of 7.5 bar was high enough to produce a concave forming, so that the material could flow from the sheet thickness to achieve the necessary elongations. Forming at a lower peening pressure would have been impractical since this would have led simply to a curving with no elongation.

The basic pattern of the shot peening with the path of the nozzle over the component and the respective mass flows is shown in Fig. 4. The similarity to Fig. 3 is obvious. This peening strategy results in the mass per unit area of the component shown in Fig. 5 for the basic pattern.

CONTROLLED SHOT PEENING

To obtain the most efficient shot peening, a ball co-ordinate system was used in which every point of the component was unambiguously identified through the specification of two angles. The necessary co-ordinate transformations between the component and plant system was carried out with the aid of a PC. The changing contour of the component during peening was taken into account through corresponding corrections in the NC programs.
An on-line interpolation system in the NC control ensured that the number of support points for the individual shot lines could be kept low. All peening parameters were recorded and documented during the process. The shot velocity was measured optoelectronically during peening (5).
During peening it was discovered that the weld seam in the middle of the component displayed a different peen hardening behaviour, making selective peening necessary here so as to avoid dents. This posed no great problems thanks to the use of the ball co-ordinate system. Measurements of the component with a laser between peenings immediately showed critical points which could lead to dents, so that these areas could be correspondingly excluded from the peening process.
A special NC-programming technology, know as "virtual masking", was employed for masking. Certain areas of the component are hereby excluded from peening during the process by inserting a baffle plate. Only the edges of these segments have to be protected against the impact of balls by covers when using "virtual masks", because otherwise there would be impairments in the welding process.

FORM-OPTIMISING ARTIFICIAL AGEING

The shot peened tank bulkheads made of material AA2219 and in condition T37* are to be brought into condition T87* during mass production through form-optimising artificial ageing, which has already been proven in the production of 1/8 segments. During this process, which takes place on a CFRP-contour shell under pressure in an autoclave, remaining deviations from the desired contour are eliminated. This means that it is no longer necessary to level the segments.

OUTLOOK

Despite the size of the component and the difficulties arising from the weld seams, we were able to prove that the ¼ segment could be successfully formed. Based on the experience gathered from the forming of 1/8 segments in connection with laser measurements and a complete recording of all peening parameters, it will, in future, be possible to form components of this size with NC-control and a complete documentation. It will be possible to react quickly and appropriately to changes in geometry.
The ¼ segments are to be given their final contour in six basic pattern treatments in which the overall degree of coverage on the surface of the component shown in Fig. 6 will be achieved. The segments are to be manufactured by the Kugelstrahlzentrum Aachen GmbH, a spin-off company of the RWTH Aachen.

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FIGURES

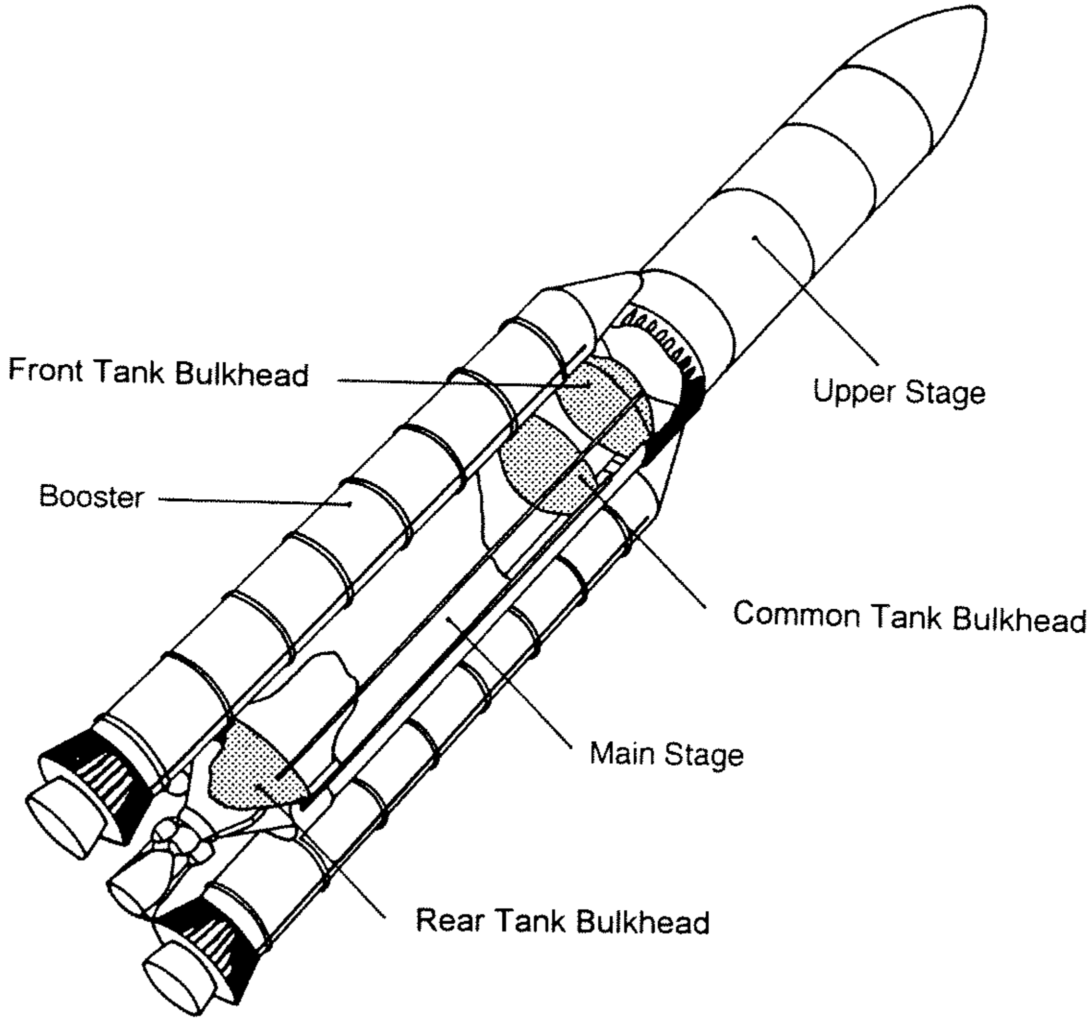

Fig. 1: Cryogenic main stage H150 of the European Ariane 5 rocket

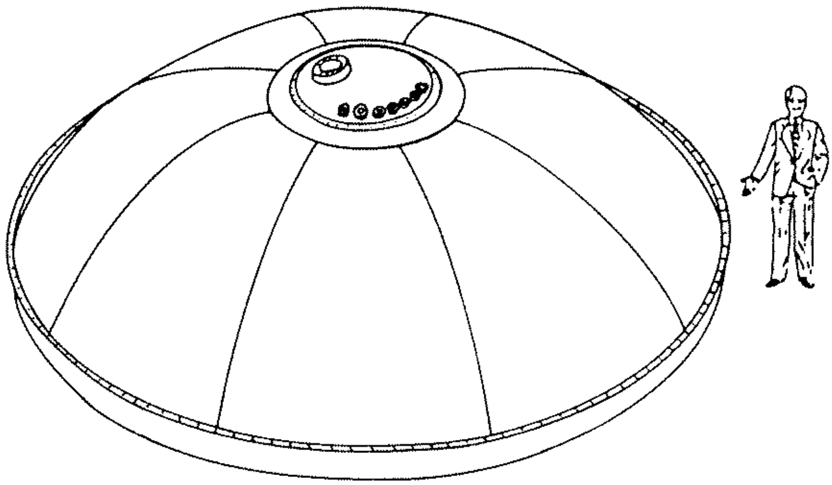

Fig. 2: Tank bulkhead of the cryogenic main stage H150 consisting of 8 segments

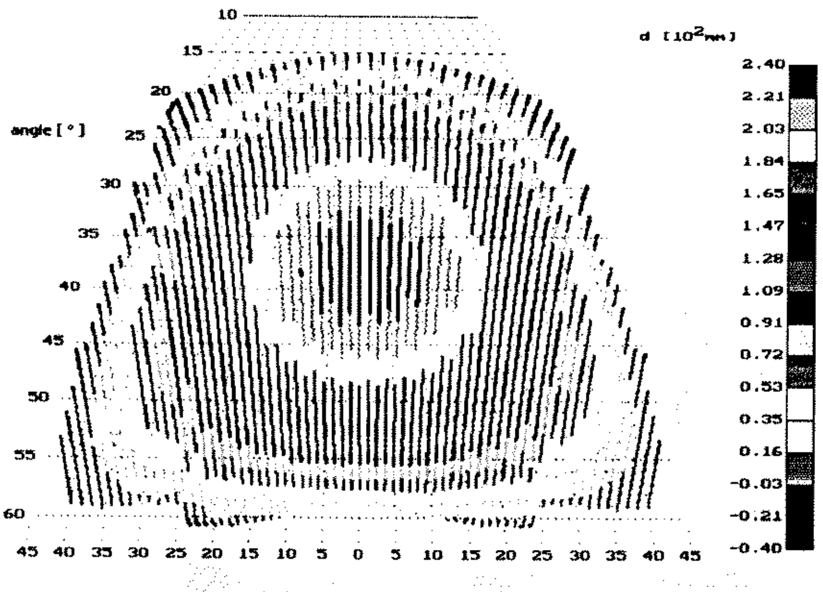

Fig. 3: Deviation in contour for the ¼ segment before shot peening

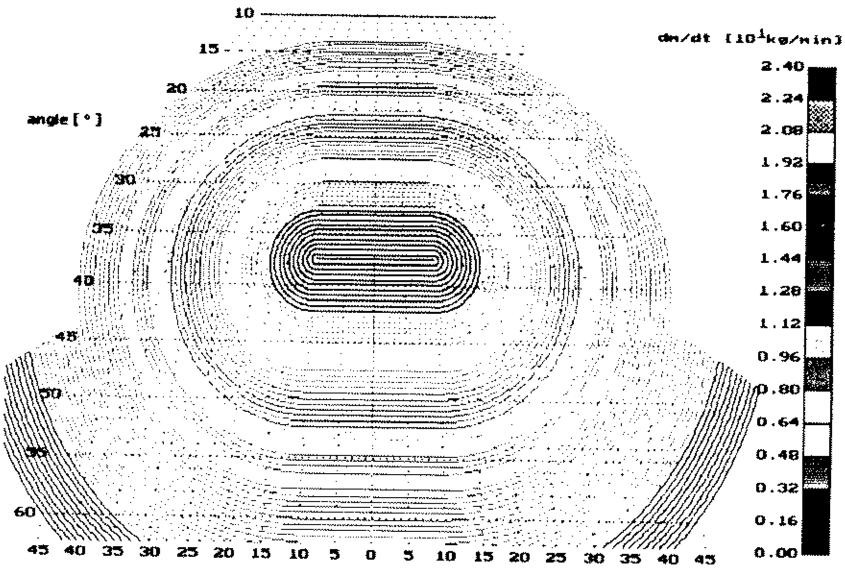

Fig. 4: Mass flow and nozzle path over the ¼ segment

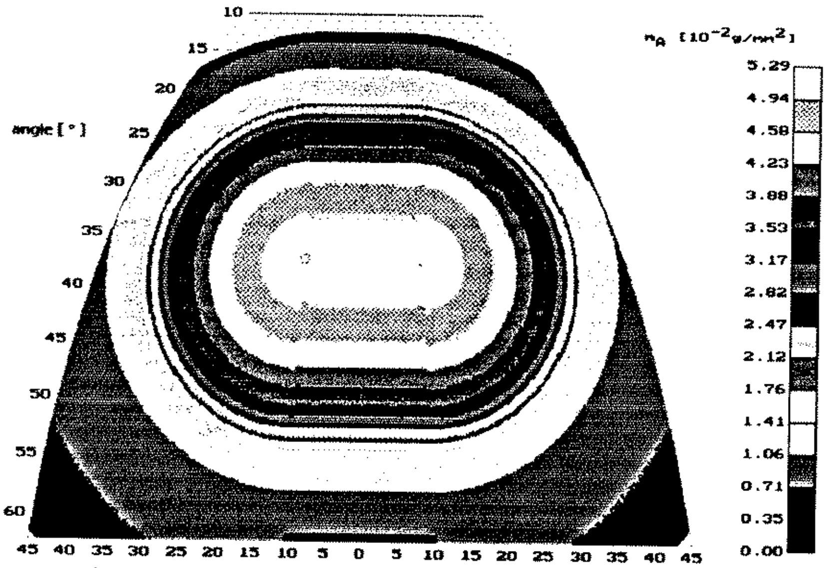

Fig. 5: Mass per unit area (basic pattern)

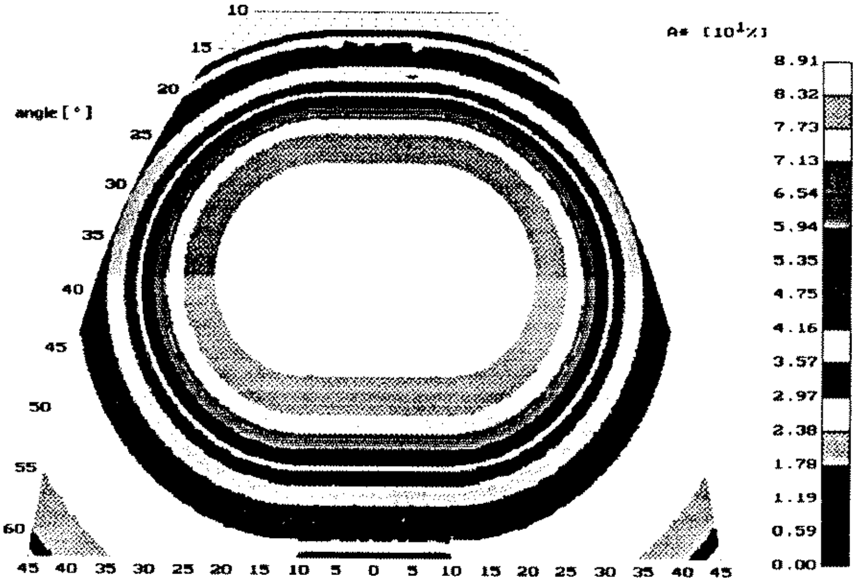

Fig. 6: Overall degree of coverage on the surface of the component