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# Towards Peen Forming Process Automation

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## 1 Introduction

The KSA - Kugelstrahlzentrum Aachen GmbH (Aachen Shot Peening Centre), a spin-off from Aachen Technical University, was founded in 1994. Its management has an approximately 25% share in the company, the majority of the shares being held by RAG Aktiengesellschaft in Essen, one of the twenty largest German concerns.

The company's aim is to establish a new way of carrying out peening in the marketplace by moving away from the widespread trial and error approach, replacing it instead by really controlled shot peening with high-level process automation.

Thereby, we prosecute an open policy in terms of full process data transparency and in this respect: our team of peen forming engineers, process engineers and automation specialists is available both on the spot to ensure the reliable performance of your process as well as for production work on a contract basis.

The advantages of our process automation include high process reliability and quality with a high level of productivity and unlimited flexibility in design.

## 2 Controlled Shot Peening

Various applications have now been developed in Aachen to the point where they can be produced in series using controlled shot peening with process automation (= *KSA -Controlled Shot Peening*). This technology has its origins in Aachen Technical University, in particular the Institute for Metal Forming, and still draws on its potential and environment.

Well over 500 side shells for the Airbus A310, about 600 structural tank segments for Ariane 4 and over 250 tank bulkhead segments for Ariane 5 have been produced successfully with shot peening to date in Aachen. We also use shot peening to form various extremely complex cone panels for the frame of the Ariane 5 power module and are currently using shot peen forming to support *Airbus Deutschland GmbH* to re-shape laser-welded skin panels [1, 2, 3] / (Fig. 1).

Despite the large number of applications, there has not been one case in our company's history where a component from series production has been rejected because of imperfect shot peening treatment. This indicates the quality and reliable performance of our controlled shot peening. Following successful qualification, the process runs on a controlled basis, is documented and can be reproduced exactly (= *Frozen Process*).

Manual intervention in the production sequence of peening technology is neither possible nor necessary.

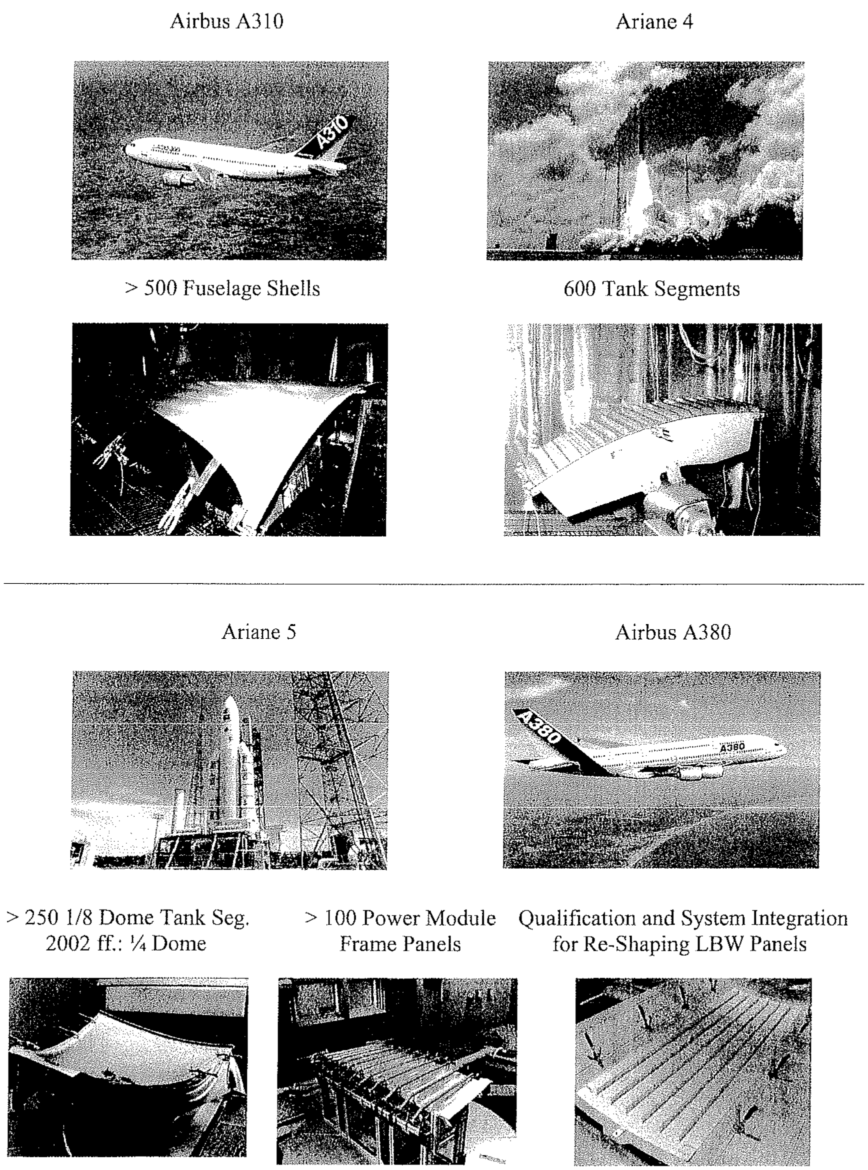


**Figure 1:** Production experiences

## 3 CNC-Controlled Shot Peening Facilities and Models

For our work we use 7-axis CNC-controlled/robot-aided shot peening facilities, our special know-how of the process with regard to the normal distribution of shot beneath the nozzle [4] as well as our models for on-line logging, evaluation and documentation of all the parameters of the peening process carried out on the component surface (Fig. 2).

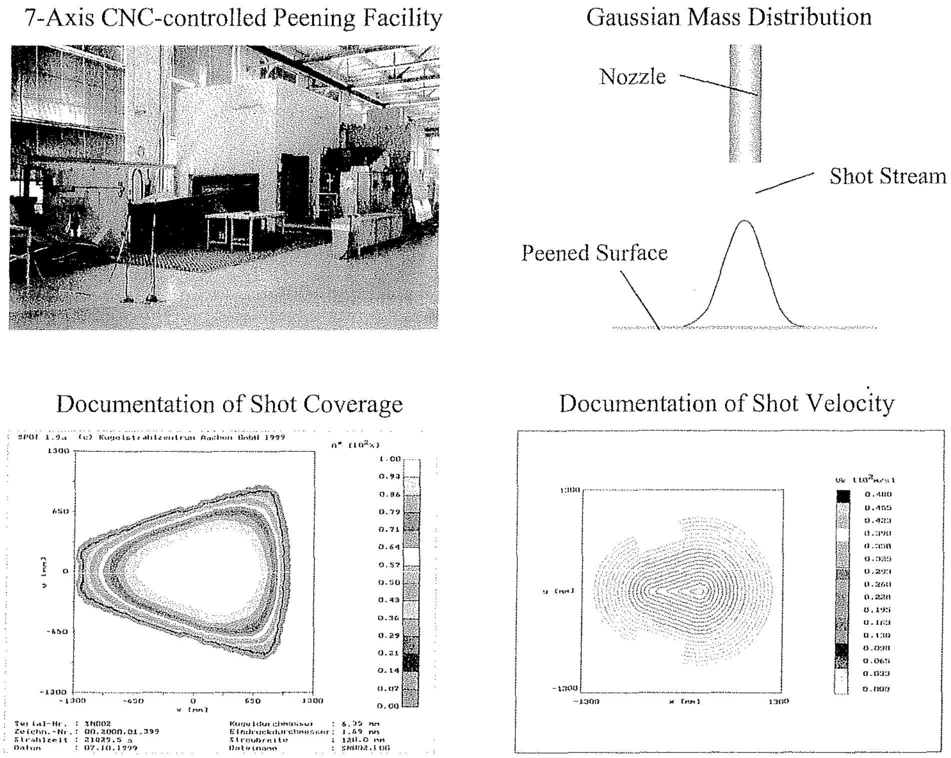


**Figure 2:** Controlled shot peening

Thereby we are the only company worldwide which can provide visual representation not only of the amount of shot used per second and its normal distribution but also of *shot velocity* directly beneath the nozzle and the degree of *shot coverage* on the surface of the component. This has finally put an end to trial and error approach in shot peening and has facilitated clear description of the influences on the material caused by forming.

A further innovation is that our customers receive complete documentation for each component, which explains what happened on the component surface itself. Our customers speak of *Shot Peening – Improved Technology* or even of *New-Generation Shot Peening.*

## 4 Process Implementation

We would like to outline our unique controlled shot peening process using the example of the current production of tank segments for the European rocket Ariane 5 (Fig. 3). This rocket has five spherically curved tank bulkheads which are currently assembled from eight individual segments for technical reasons. All the tank segments are made from the aluminium alloy 2219 T37* / T87*, the thickness of the sheet in the field varying from 1.6 mm to 3.5 mm and widening in stages towards the edge up to a maximum of 6.4 mm (= *Integral Construction / High Design Flexibility*).

Our task is the precise and reproducible conversion of this integral component from the flat state in which it is delivered into the spherical contour R = 3004,6 mm ± 4 mm. Thereby, the maximum reduction of sheet thickness is 0,1 mm (= *Customer Requirement*).

Depending on the thickness of the component, we use shot of varying diameter (4.75 mm – 9.575 mm) and carry out various steps in sequence as well as concave peening with high peening pressure and through-forging of the cross-section of the component (= *Concave Peening / Partial Forging Process*).

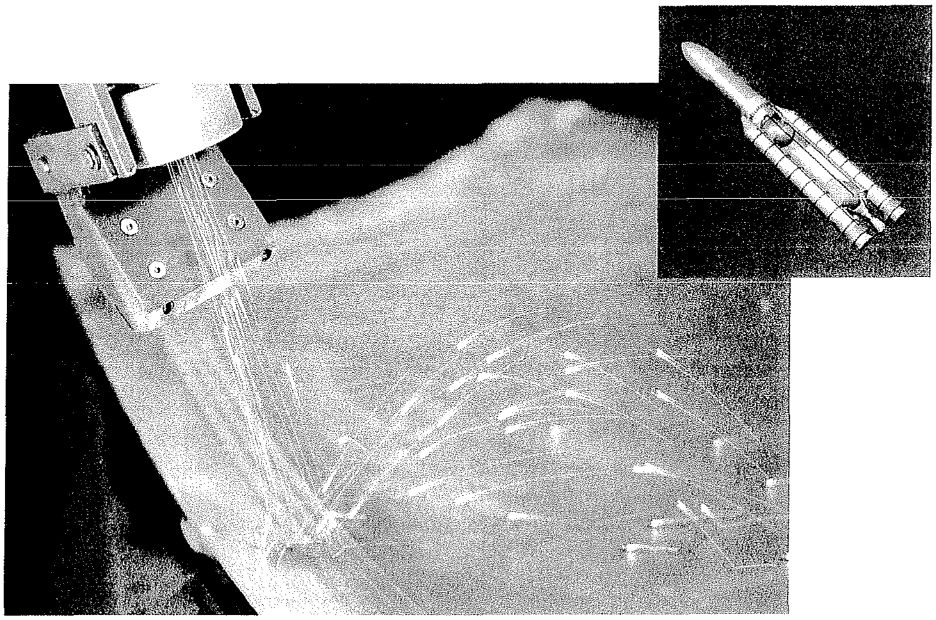

**Figure 3:** Dome tank segment of Ariane 5 during shot peening treatment

Depending on the geometry of the component, the sequential steps of the process are: five basic treatments, three homogenisation steps, 1 convex and 1 concave step for treating the edge as well as a maximum of eight field correction steps.

In order to ensure high production standards for such components, a modern 7-axis CNC-controlled shot peen forming facility was put into operation in Aachen at the Institute for Metal

Shaping at the beginning of 1993. This was originally a research and development facility with the aim of serving as a foundation stone for the development of a shot peening centre in Aachen.

The facility features a continuous compressed air peening system with a nozzle for shot of up to 4.00 mm in diameter as well as a combined injector-gravitation peening system for shot of up to 10 mm in diameter. It is designed for forming components with maximum dimensions of 6,000 x 3,000 x 1,500 $mm^3$ (length x breadth x height) and can be positioned to an accuracy of ± 0.1 mm for the x, y and z axes and to ± 0.1 degree for the possible rotary and slewing motion of the component (v and w axes). The components are charged using a transport wagon on rails with a possible rotary and slewing motion (c and a axes).

## 5 Control Units

The next Figure shows a diagram of the control PC and control unit for our on-line logging and documentation of the process parameters (Fig. 4). These enable us to carry out *off-line programming* on the basis of CAD data, *on-line logging of readings* as well as *on-line documentation and evaluation* with data output (Fig. 5).

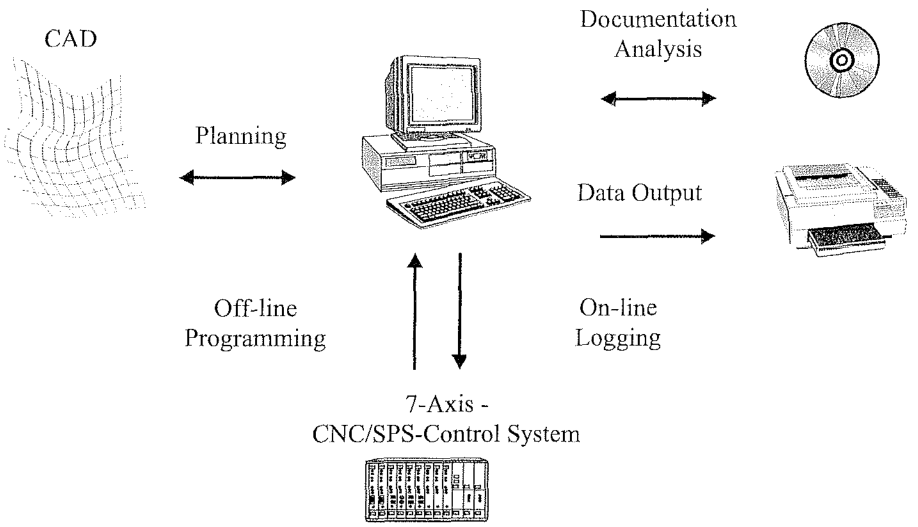


**Figure 4:** Control unit and control PC for on-line control and documentation of the peening process parameters

Apart from providing *conventional information* such as the current axis position, peening pressure, the shot dosing or the velocity of the nozzle over the component, *essential data for the forming process* is logged on-line and presented in visual form on our peening facilities for the first time.

This includes the *number of registered particles per second* (= *shot as a tool*) and their *normal distribution* (= *mass per surface*) and, for the first time, *shot velocity* and *shot coverage* on the component surface itself as a function of the place and time of peening.

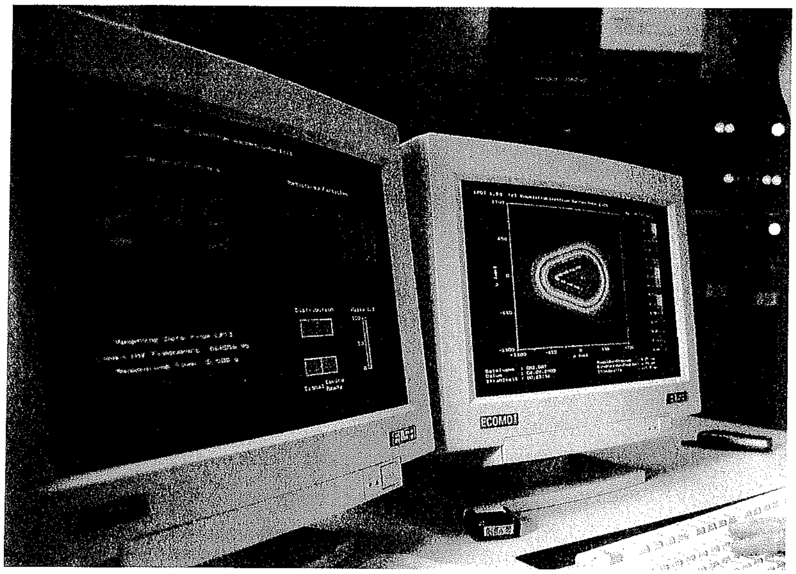

**Figure 5:** On-line logging and control of all essential peening process parameters

## 6 Process Automation

Each segment is accompanied by a forming programme, storaged on disk/CD-ROM, on which all the forming steps and processing times are chronologically recorded. The production process takes place with full computer control, thus eliminating any errors in processing the component.

In order to determine the final field correction steps, the component is measured outside the peening chamber on a 3D measuring gage (Fig 6). The contour which was achieved is logged electronically using a measuring sensor and any deviations from the target contour are represented by contour lines with a similar deviation from the target contour R = 3004.6 mm (Fig. 7). Then the facility programs the necessary field correction steps fully automatically, as seen in the diagram of the field correction steps 1 – 4.

We have had an optoelectronic, integrated 3D final component measuring feature on our new 7-axis CNC-controlled/robot-aided shot peening facility since 2001 (Fig. 8). Currently we are working on qualifying production of double size ¼ dome segments using this second, highly-modern shot peening facility (= *Flexibility in Process and Design*).

The ¼ dome segments are peened simultaneously from both sides [5] using two articulated industrial robots, thereby considerably reducing run times and optimizing the sequential steps of the process (= *Learning Curve Effects*).

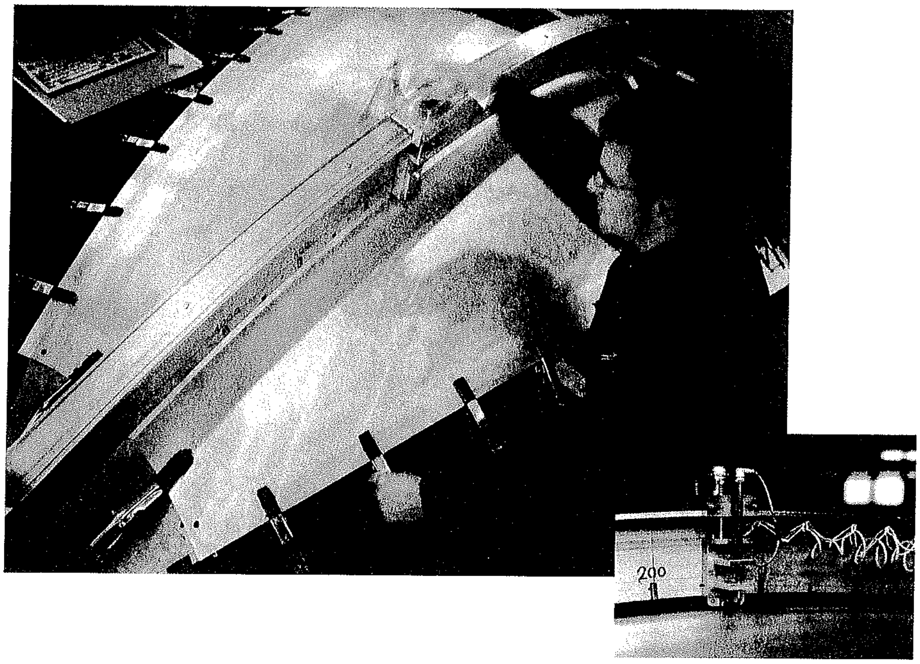


**Figure 6:** 3D contour measurement

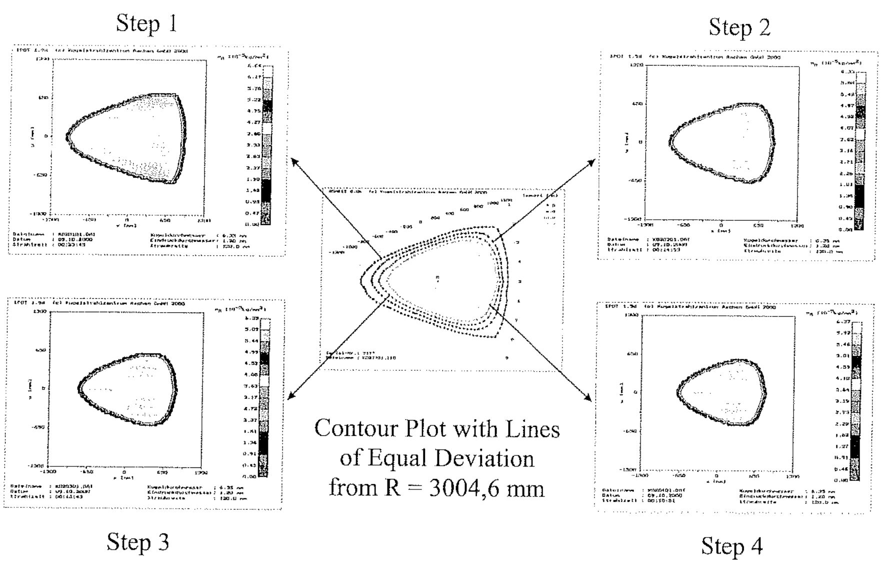


**Figure 7:** Computer-aided calculation and programming of the final field correction steps 1–4

## 7 Customer Benefits

Controlled shot peening with process automation takes place on CNC-controlled shot peening facilities in a way which is controlled, documented and can be reproduced precisely (= *High Process Reliability*).

Our new-generation peening facilities feature central control units which facilitate off-line programming and on-line logging, evaluation and documentation of all the parameters essential for the peening process (= *High-end Process and Model Technology*).

Each segment is accompanied by a forming programme. The production process is fully computer-controlled, thus eliminating any errors in processing the component. (= *Process Automation*).

This ensures high quality (= *Quality*), optimum process sequencing (= *Technology*) and reduced run times (= *Profitability*).

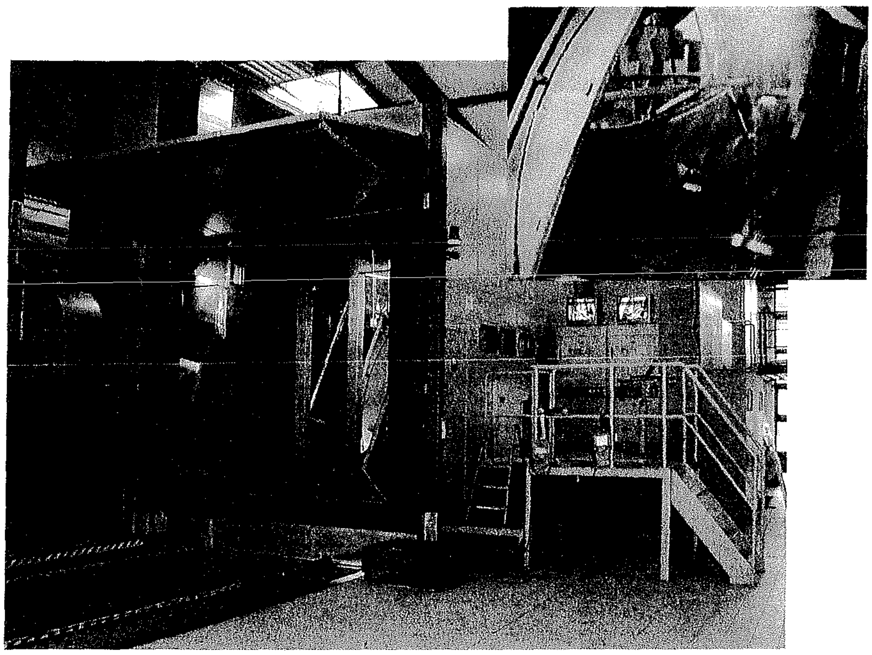

**Figure 8:** Modern 7-axis CNC-controlled shot peening facility with two articulated industrial robots and integrated 3D measurement / facility 2

## 8 Summary

The market increasingly expects stable and automated processes with high process reliability and practical flexibility in design.

Controlled and automated peening processes have put an end to the trial and error approach to the shot peening process and facilitate clear description of the influences of forming on the material. Each processing step can be traced and identified at any time. Thus, the lack of clarity which characterized the shot peening process has given way to transparency, resulting in an industrial process which permits a breakdown of the individual steps.

Production and quality control are process-oriented and completely fulfil the requirements of DIN ISO 9001 - 2000.

## 9 References

[1] F. Wüstefeld, Metal Finishing News 2000, December Issue, page 9–10, Shot Peening Process Automation for the Aircraft Industry

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[4] F. Wüstefeld, DGM Informationsgesellschaft mbH, 1993, Modelle zur quantitativen Abschätzung der Strahlmittelwirkung beim Kugelstrahlumformen

[5] F. Wüstefeld, Metal Finishing News 2001, November Issue, page 18–19, Shot Peening Forming of new ¼ - Dome Tank Segments for Ariane 5