ON-LINE PROCESS CONTROL FOR SHOT PEENING APPLICATIONS

2005111

Frank Wüstefeld, Wolfgang Linnemann, Stefan Kittel, Axel Friese

KSA Kugelstrahlzentrum Aachen GmbH, Weststraße 24, 52074 Aachen, Germany

ABSTRACT

Kugelstrahlzentrum Aachen GmbH (KSA), a company specialized in shot peening services and automation solutions, and Rolls-Royce Deutschland (RRD), a subsidiary of Rolls-Royce plc, are currently working together to develop and test an improved process control system for shot peening applications. The common goal is a system for monitoring peening intensities on-line in order to reduce Almen tests and consequently to cut process times and costs.

In the context of this joint project, KSA has down-scaled its shot velocity measurement system to measure smaller shot sizes down to 0.1 mm. The *ISIC*-system *(Integral Shot Intensity Control)* is able to detect shot velocities of ferrous and non-ferrous peening media as well as mixtures of different media sizes. The main results are at present: A clear linear correlation with Almen intensities, even higher sensitivity and an ability to quantify the influence of varying shot sizes and particle distribution.

SUBJECT INDEX

Shot Velocity, Particle distribution, Shot Size, Shot Intensity, Process Control

INTRODUCTION

The result of a peening treatment depends firstly on the process parameters, i.e. the machine type, nozzle geometry (spread, diameter, distance), shot type (material, form and size), mass flow, shot velocity, strike angle etc. and secondly on the material parameters of both the shot and surface, i.e. on their hardness, strength, structure, microstructure etc.. These parameters – which are commonly known in shot peening as the multitude of influencing parameters – combined determine the diameter of the shot indentation and therefore of the indentation area on the surface (Fig. 1).

The sum of all the shot indentation areas in proportion to the complete exposed surface results in the degree of shot coverage achieved. The shot coverage beneath nozzles, spinner wheels or peening lances occurs as a normal distribution (injector gravitation systems), poisson distribution (spinner wheels) or primarily equal distribution (continuous peening pressure systems).

Using advanced hardware and software, it is already possible today in peen forming applications with shot of approx. 2 – 10 mm in diameter to determine the various shot indentation diameters and spread of the nozzle on-line as a function of shot intensity, and to calculate, adjust and document the degree of total coverage on the component surface itself (Fig. 2). The mathematical models required for this are based on the basic relations of the "mathematics of normal distribution" and the "superposition principle for any occurrences" (Wüstefeld, 2002). A necessary prerequisite for proceeding in this way is working with CNC-controlled or robotguided facilities, which supply the corresponding models with the current nozzle and facility positions.

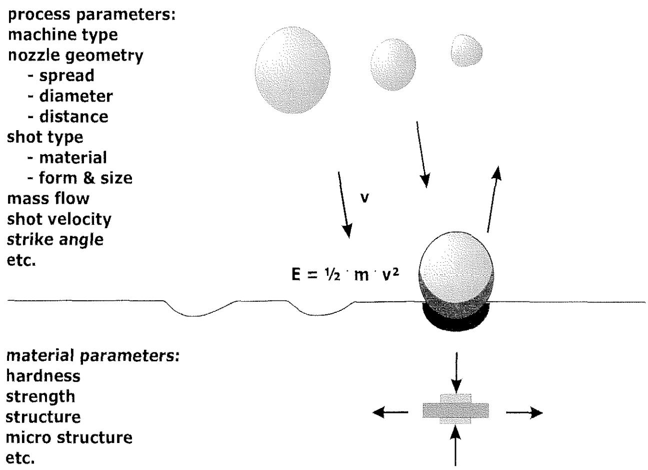

Fig. 1: Parameters influencing shot peening processes

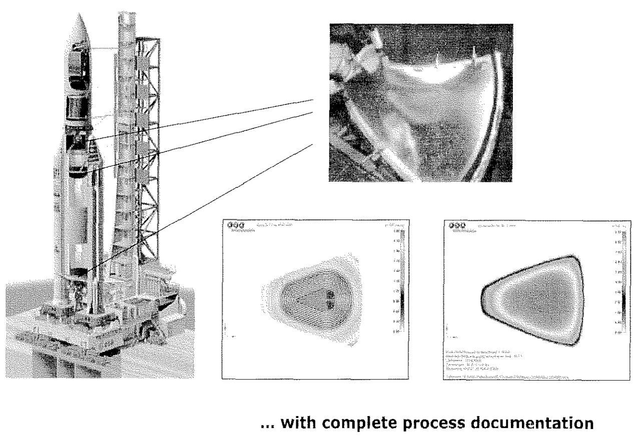

Fig. 2: State-of-the-art on-line process control for fully-automated shot peen forming of an Ariane 1/8 dome tank bulkhead segment

The challenge is rather different for shot peen hardening processes: Here we are faced with complex geometries featuring sharp edges and undercuts as well as ricochets. Furthermore, the shot in use is smaller by a factor of 10 - 20. However, in order to record the effect of the shot media in a shot peening treatment, the parameters have also to be recorded integrally here, i.e. as a function of peening time and location.

METHODS

Current method: Almen intensity

Seen in terms of physics, the intensity of a peening treatment is an energy flow density of the unit W/mm^2, i.e. the energy which penetrates a certain surface within a certain time. Almen intensity, on the other hand, is the arc height of a standardized test strip in mm.

Almen intensity also yields an integral statement on the energy introduced through the peening process in that Almen strips (i.e. certain surfaces) are exposed to the shot fan for a certain time in place of the original component, leading to a measurable curvature of the strips. When saturation level has been reached, this curvature is used as the measure for intensity (Almen, 1944). At present, this is the accepted method for determining peening intensity.

If the velocity and distribution of the shot media are continuously recorded and correlated with the Almen intensity, it becomes possible to regulate a peening process using this data and to reduce the costly use of Almen strips.

Some processes for the on-line measurement of particle velocity now exist on the market, and the influence of shot velocity on the peening results has been described in detail in numerous publications (Linnemann, 1996; Zinn, 2002). The interrelations shown in Fig. 3 can be considered as established and are indicative of the present state of technology.

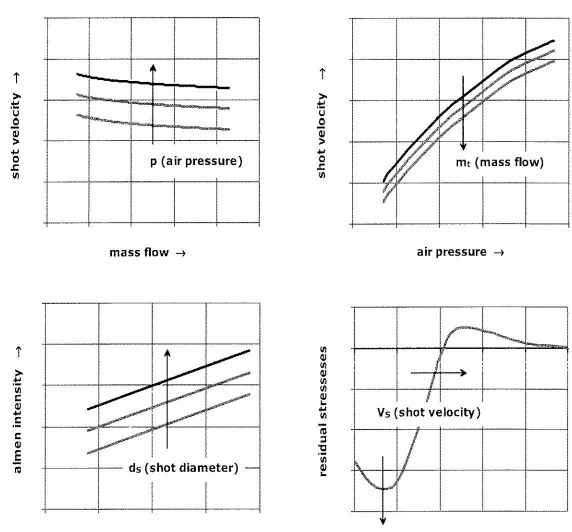

Fig. 3: Interrelations (schematically)

KSA and Rolls Royce Deutschland are currently working together to develop and test an improved process control method for shot peening applications (Haubold, 2005). The joint project was initiated at ICSP 8 in September 2002.

The aim of the joint project is to develop a practicable measuring system for on-line process control and to introduce this into the production process, thereby achieving a reduction in costly Almen intensity measurements. The system currently in the test phase at RRD is a further development of the shot velocity measurement system which has been developed and tested during peen forming at KSA since the middle of the nineties.

New method: *ISIC - Integral Shot Intensity Control*
The new method is based on the optoelectronic measurement of the number of particles and their velocity, and was patented in 1996 (European Patent EP 0 678 748 B1 and United States Patent 5,691,483). The particle velocity is measured with two light barriers consisting of a diode laser as the source of light and two optical fibers with a diameter of < 0.25 mm (Fig. 4). The detected signals are processed further on a connected PC. The system, which is protected from dust by an air curtain, can record the velocity of both metal and non-metal peening media down to a diameter of 0.1 mm. The dimensions of the sensor can be adapted as required depending on the individual application.

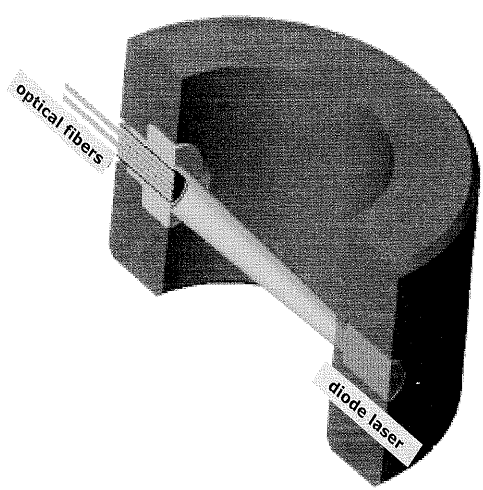

Fig. 4: Measuring Principle of the *ISIC-system (Integral Shot Intensity Control)*

RESULTS
The first tests of the *ISIC-system* have already provided promising results for its implementation as a new process control tool at RRD's shot peening facilities. At present there are 3 significant test results which are the basis for KSA's further development of the system:

Result 1: Shot velocity function

The measurements of the shot media velocity and Almen intensity show a definite dependency on pressure. Variations in shot media velocity prove to be much less pronounced here than those of Almen intensity. Changes in peening pressure of 0.1 bar are recognized by the system and the required accuracy of 0.02 mm Almen intensity is maintained.

The sensitivity of the *ISIC*-system shown in numerous test series is at least comparable to Almen tests. The velocities measured display the established linear relation to Almen intensity.

Result 2: Measurement of velocity and particle distribution

Of particular significance is the fact that the measuring process not only enables the velocity of individual particles to be measured but also the shot fan of various accelerating tools (nozzles, spinner wheels, peening lances etc.) To do this, the tool is placed at right angles to the measuring device and the number of particles is measured at each position for a defined period. Fig. 5 shows the results of this process for a shot peening facility at RRD.

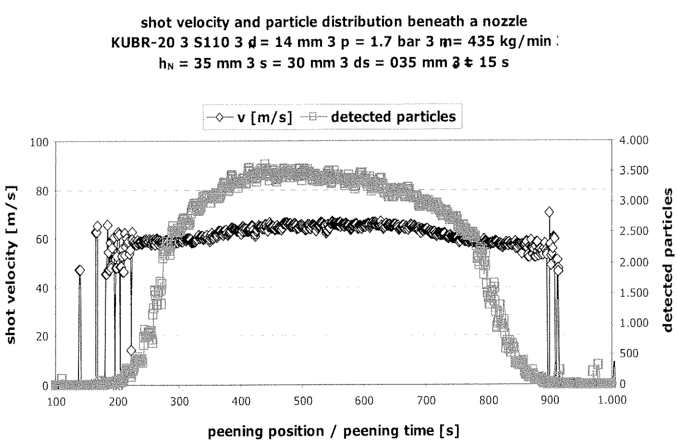

Fig. 5: Shot velocity and shot distribution beneath a nozzle

Besides confirmation of the expected primarily equal distribution (continuous peening pressure system), the main result is that the velocity and number of particles hardly changes over the complete central area of the nozzle diameter. This means that the precise position of the nozzle in relation to the *ISIC*-system is not of critical importance.

The next figure shows the *ISIC*-system installed in a shot peening cabinet for test purposes, a screen shot of the on-line measurement system and the sensor of the measuring device (Fig. 6).

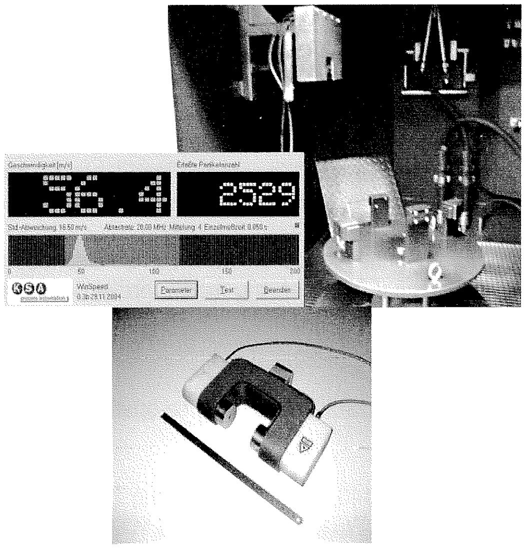

Fig. 6: *ISIC*-system and a screen shot of *ISIC D*isplay

In the current series of tests and later in constant process control, the *ISIC*-system will be mounted inside the peening cabinet. Rather than the measuring system being guided to the nozzle, the nozzle tools will be guided to the measuring system.

Result 3: Influence of shot size distribution on Almen intensity

In pressure peening systems, the velocity of a particle is approximately in inverse proportion to its diameter. The influence of sieve analysis and the size distribution of the peening media on velocity distribution cannot therefore be ignored. The *ISIC-system* takes this influence into account by determining particle size distribution in advance in calibration measurements, and by taking into consideration its influence on Almen intensity within the plotting algorithm.

DISCUSSION

It has been demonstrated that the *ISIC*-system is able to determine shot velocities with at least comparable sensitivity to Almen tests. The system has proved successful and easy to handle, e.g. positioning to the nozzle is not of critical importance.

In practical use, a process control system for shot peening applications has to deal with varying shot sizes due to shot mixtures, shot wear etc. The system which has been developed can take into account the three factors of shot velocity, shot distribution and the effect of different media sizes. All the parameters are recorded integrally, i.e. as a function of peening time and location.

The main task for further development is to evaluate statistically the influence of shot size and particle distribution on Almen intensity and to integrate this influence into the system's statistical algorithm.

CONCLUSION AND IMPLICATIONS

KSA has down-scaled its shot velocity measurement system for smaller shot sizes down to 0.1 mm. The system is able to detect ferrous and non-ferrous peening media as well as mixtures of different media sizes.

The benefits of advanced process control and the *ISIC*-system include improved quality (fewer cases of process failure) as well as reduced run times and costs. A reduction in Almen strip testing will result in reduced lead times for components and a more efficient use of production resources (e.g. machine capacity, operators).

The system's potential for advanced process control can be extended even further to include aspects of quality control (e.g. peening media, preventive maintenance) and self-controlled closed-loop shot peening processes.

ACKNOWLEDGEMENTS

We wish to thank Rolls-Royce Deutschland for their co-operation.

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