Implementation of velocity measurement as intensity verification in production

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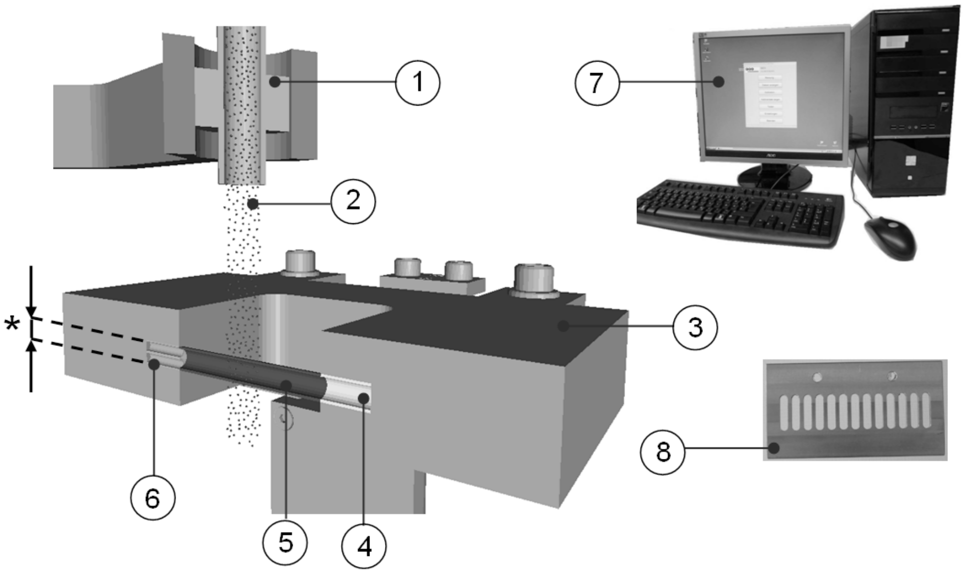
Abstract
The current method for determining shot peening intensities and to verify process parameters in production is to use Almen strips and saturation curves. Even though it is a well established process it still has some disadvantages. For example, measurements can not be stored over a longer period of time due to relaxation of the material, online intensity verification is not possible and the whole process itself can be quite time consuming, depending on the complexity of the part to be peened.
In order to find another process which can be used more conveniently, intensity verification by means of velocity measurement of the peening media was investigated.
Different parameters which are known to influence the peening intensity were varied and their effects on the shot velocity were documented.
Pressure, shot flow, type of nozzle, type of peening media, as well as hose bending and peening angle are among the variables tested. Two different methods of velocity measurement were used and compared with one another. A long-term study under production conditions was carried out to test the stability and reliability of the measurement process.
Based on the results, the potentials of the velocity measurement were identified and possibilities were explored to include this process in production as a substitute for or alternative to Almen strip measurement.

Keywords Velocity, intensity, almen, ISIC, shotmeter

Introduction
Increasing quality and cost-effectiveness requirements in production not only require suitable machines and qualified personnel for defined manufacturing processes but also improvements and innovations in the field of process monitoring. For controlled shot peening, the Almen strip method has so far been the only approved measuring method for determination of parameters and process monitoring. Long established in production, however, the method has several disadvantages: Because of the relaxation of stresses, long-term storage of the Almen test strips does not make sense. Online measurement is not possible and, depending on the complexity of the component involved, peening and evaluation of Almen strips may be rather time-consuming. As an alternative measuring method that would take less time and hence increase machine availability and improve process monitoring, measurement of the velocity of the peening media particles was investigated to determine the suitability of the method for process monitoring purposes.
At first, the setup and function of the “ISIC 2” *(Integral Shot Intensity Control)* velocity measuring system developed by Kugelstrahlzentrum Aachen GmbH (KSA) and the standard measuring setup in the peening cabinet are described. Then the test results are presented. Since a large number of parameters were investigated, only those results are dealt with in greater detail that are of special relevance when deciding on the introduction of the velocity measurement in production. Further results can be shown for information only.
Finally, the results are summarized and the potential of the method is assessed. This paper is intended to provide evidence of the suitability of particle velocity measurement for monitoring the shot peening process.

Experimental Methods
Fig 1 shows the velocity measurement system „ISIC 2“. The system comprises a sensor that is placed in the peening cabinet and a personal computer for detection of signals, calculation and display of measurement values. The sensor is made of a hardened steel housing with a diode laser and the ends of two fiber-optic cables as a light barrier inside. The laser projects a continuous light spot on the ends of the fiber-optic cables. The laser's light signal is transmitted by the fiber-optic cables to two photo-electric cells on a measuring board inside the personal computer.
Media particles pass the laser beam during the measuring process and black out the beam temporarily. This causes darkening first at the upper light barrier and then at the lower one. The time between darkening of the first and second light barrier is measured and the particle velocity can be calculated based on the known light barrier distance.
During peening, a large number of media particles pass the sensor. From the resulting large number of measuring signals the noise signals are filtered out, and a statistical method is used to calculate the particle velocity. The measurement results are displayed continuously and in real time on the screen and can be stored in a file. The new system permits single measurements, several measurements laps as well as continuous measurements to be performed.



* velocity: signal time shift and distance between 1st and 2nd light barrier

Fig 1: Velocity measurement sensor „ISIC 2“ 1: Nozzle and nozzle holder / 2: Peening media / 3: Sensor housing / 4: Laser / 5: Laser beam / 6: Fiber-optical cable 7: Computer and velocity display / 8: Calibration fence

The velocity display screen is shown in Fig 2. The current velocity value in [m/s] is shown in the central area. On the right side, the measurement period per lap and the number of detected particle are displayed. Below is a diagram of the statistical distribution where the value of the highest frequency is equivalent to the velocity value displayed. Once a measuring process is started the development of the measurement value is continuously displayed in the left area. Thus, it is possible for the first time to identify process fluctuations in real time. At the end of a measuring process the average velocity values per lap are displayed. Furthermore, in the event of continuous measurements the file of measured values can be analyzed.

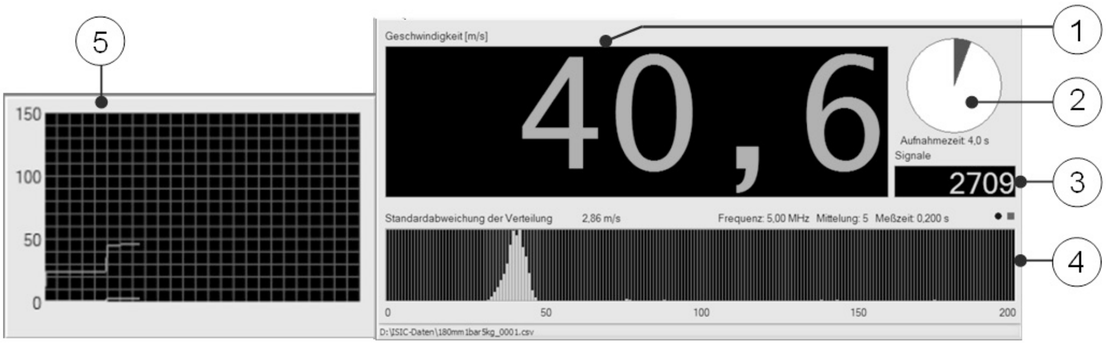


Fig 2: Particle velocity display screen 1: Velocity value / 2: Measurement period / 3: Number of particles detected / 4: Velocity distribution / 5: Development of the measurement value

As shown in Fig 3, the nozzle is positioned above the sensor and the media passes the light barrier perpendicularly. The measuring distance is equivalent to the distance between nozzle and part to obtain a direct correlation.The peening medium used for the tests was conditioned cut steel wire with a size of S110 as this is the medium primarily used on the CNC pressure peening facilities in MTU's production shops.

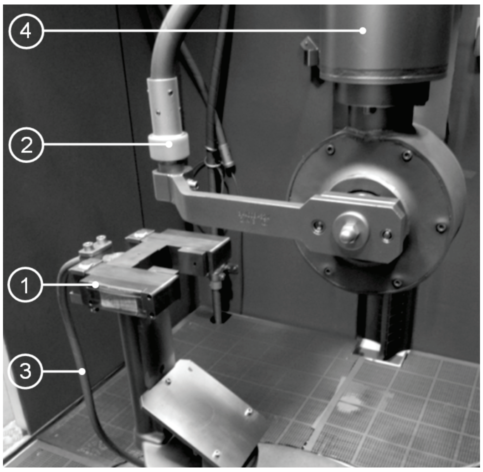


Fig 3: Measurement setup 1: Sensor ISIC 2 / 2: Nozzle holder with nozzle / 3: CNC manipulating system 4: Fiber-optical cable and electric cable for laser

Experimental Results

First basic trials had been performed to investigate the influence of shot peening process parameters, to identify limiting factors for velocity measurement und to get experience with the use of the sensor. As shown in Fig 4, the results obtained for pressure, shot flow rate and velocity variations are similar to those presented by KSA and Progressive Surface™ (formerly Progressive Technologies, Inc.) at the „ICSP9“ in 2005. The shot peening process velocity range is between 20 - 100 m/s.

Pressure variations have much more influence than changes to the shot flow rate. With increasing nozzle diameter the velocity decreases. Just like nozzles, machines show individual characteristic lines of velocity.

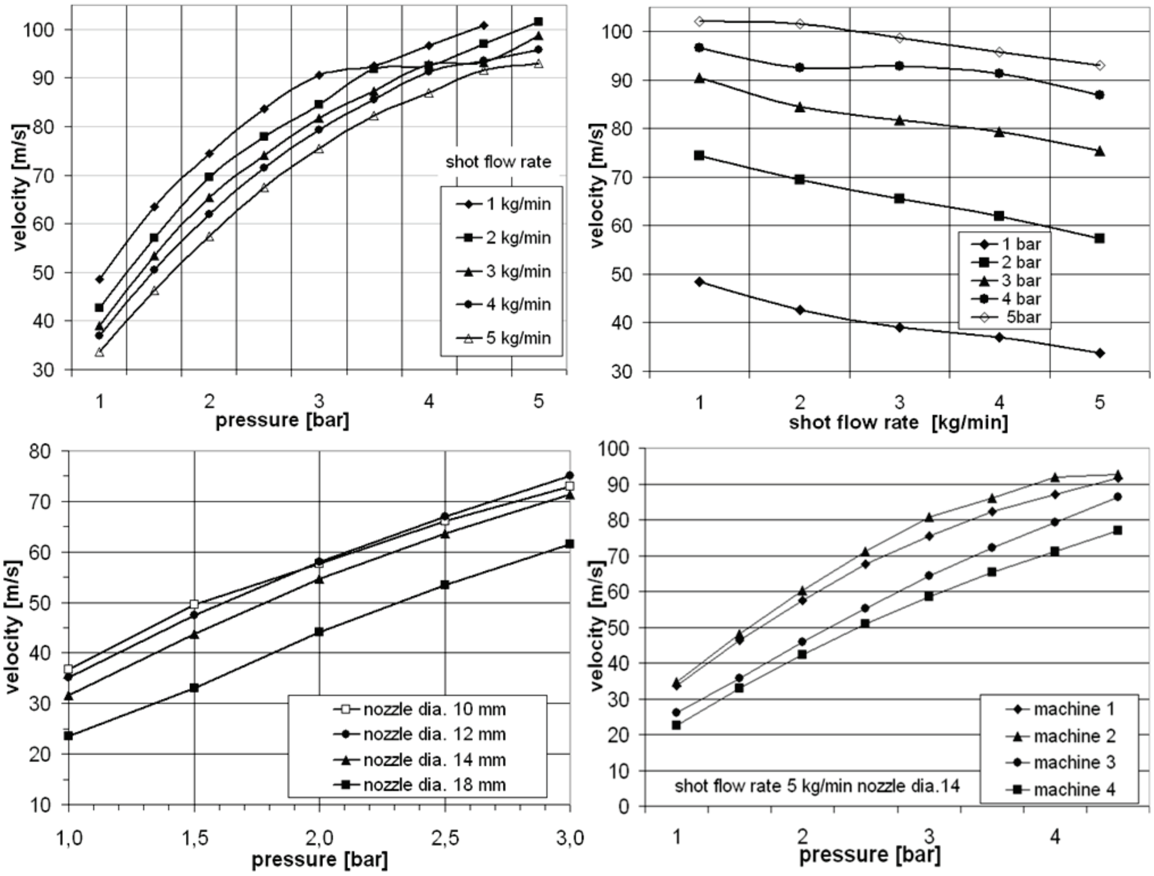


Fig 4: Basic trials: pressure, shot flow rate, nozzle diameter; machine

The suitability of the velocity measurement technique was demonstrated in comparable tests also for usual nozzles, nozzles with shot stream deflection as well as for media of different sizes and materials (glass beads). The influence of the measuring position (distance, angle) can be disregarded for the positioning accuracy ranges of the shot peening equipment. Shot peening distance variations produces similar results as almen tests. In further tests the sensor position in the peening cabinet, hose bending and shot stream direction (e.g. direction opposite the direction of gravity) were varied. The results achieved were in good agreement. Thus it could be shown that the velocity measurement is independent of the measuring position in the peening cabinet and nozzle orientation.

In a next step, the effects of velocity on the peening intensity were investigated. As exemplarily demonstrated for an impingement angle of 70° in Fig 5 there is a linear relationship between both parameters.

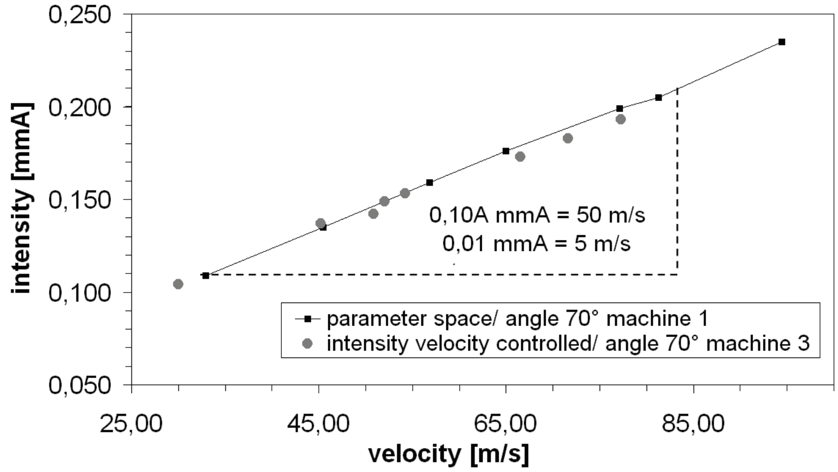


Fig 5: Velocity and intensity for an impingement angle of 70°

It can be determined that a velocity alteration of 5 m/s results in an intensity alteration of 0.01 mmA. 1 m/s thus corresponds to 0.002 mmA. This is the range of the measuring accu-

racy of almen gages that is specified with ± 0,0001 inch / ±0,0025 mm. For impingement angle and intensity a sine-shaped relationship was established. In further tests it was found out that – irrespective of machine type, nozzle size, and shot flow rate – the same intensity is achieved with the same velocity and impingement angle as demonstrated for machine 3 in Fig 5. The parameter used to control the velocity was the peening pressure. Taking the impingement angle into account, intensity can be set directly by controlling the shot velocity.
For further testing of velocity measurement comparative measurements were performed using the "Shotmeter" system from Progressive Surface™ & TECNAR Automation . This velocity measurement system had also been presented at the "ICSP 9" in 2005. To minimize measuring errors the sensors were positioned face to face in the cabinet as illustrated in Fig 6 and measurements were performed simultaneously. The nozzle was arranged centrally between the two sensors and set for a shot stream direction perpendicular from top to bottom. The measured values were continuously recorded for a period of 120 seconds and the peening pressure was increased from 1 to 2 and 3 bar. As can be seen from Fig 6 the peening pressure changes appear as steps in the diagram.

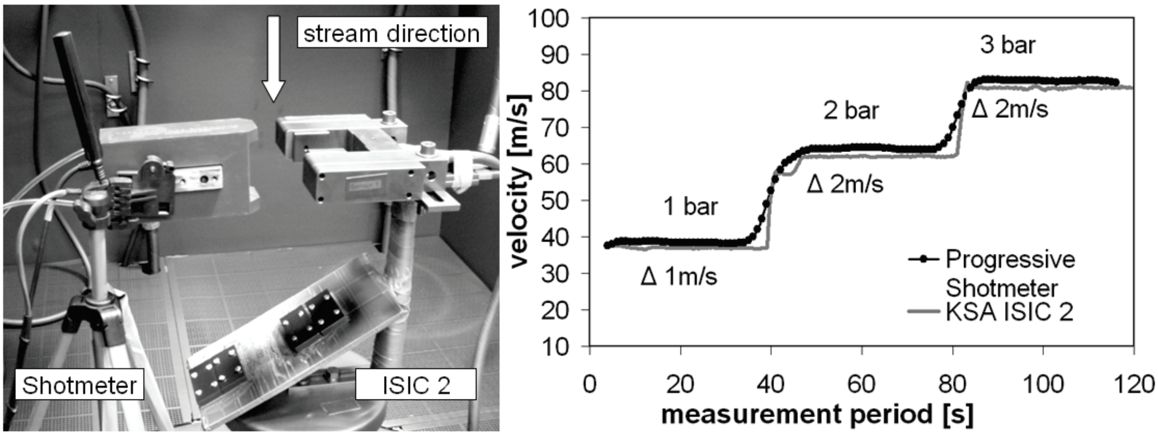


Fig 6: Parallel measurements using Shotmeter and "ISIC 2" left) set up right) results

The velocity values of measured using the "ISIC 2" and "Shotmeter" systems match closely. The maximum deviation is 2 m/s. The reason therefore could be a difference in sensor calibration. However, the deviation is within the measuring accuracy range of almen gages as can be seen from Fig 5. In summary, this experiment shows conforming results of both measurement systems in spite of different functional principles and demonstrates convincingly the suitability of velocity measurement. The method of continuous recording used gives an idea of the potential for online velocity measurement that is not possible with Almen strips.
Under production conditions a long-term study was conducted over a period of one year to investigate the correlation between velocity measurement and arc height. At the same time, reliability and sensor handling in production were investigated. In the process, the velocities were measured with the same parameters after almen strip peening for selected parts using two different machines. Correlation is very close, as is exemplarily illustrated in Fig 7 for one Almen strip (one set of parameters). Fluctuations of arc height are equally reflected in the velocity.

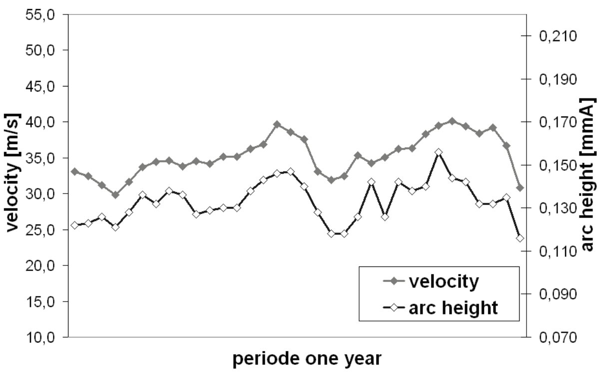


Fig 7: Long-term study usual Almen strips (intensity 0,10 – 20 A)

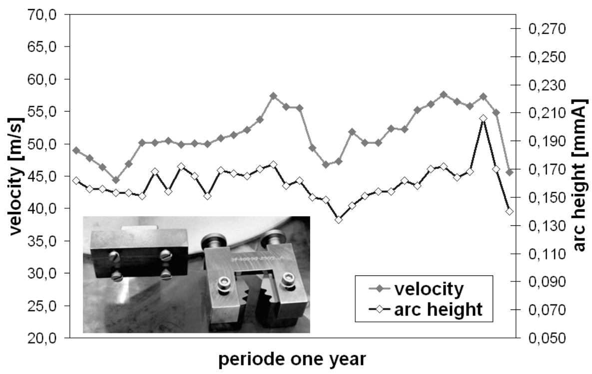


Fig 8: Long-term study using scrap part simulating the slot area (intensity 0,14–28 N)

Fig 8 shows the long-term study results for almen blocks simulating dovetail slots. A close correlation can also be seen here. Further long-term studies for special nozzles with shot stream deflection and tests on other machines show comparable correlation results for arc height and velocity. In summary, velocity measurement can be considered an equivalent alternative to the Almen method.

Discussion and Conclusions

The experiments demonstrate that velocity measurement is suitable for shot peening process verification. The basic trials show that there are no limiting factors for velocity measurement. The effects of parameters could be identified and parameters are controllable. The results presented at "ICSP 9" could be verified. A linear relationship between intensity and velocity was found. Taking the impingement angle into account, the velocity value provides an immediate information about the intensity. That is why velocity measurement is a suitable tool for process investigations and monitoring. Conforming results of the "ISIC 2" and "Shotmeter" measurement systems additionally confirm the suitability of velocity measurement. Long-term studies in a manufacturing environment show close correlation of arc heights and velocity values and demonstrate that velocity measurement is an equivalent method.

In component tryouts, saturation curves will continue to be used for determination of the process parameters. Additionally, the velocity will be measured for this set of parameters (nozzle, pressure, shot flow rate etc.) and the velocity tolerance must be defined. In production, the Almen strip measurement can be replaced by velocity measurement for this particular step. Advantages of velocity measurement include improved documentation of measured values, independence of Almen batch quality, cost and time savings and increased machine availability.

Because of today's geometrical design of CNC equipment, the sensor must be positioned in the middle of the rotary table so that it can be reached by the manipulating systems. That is why velocity measurement and peening of components are separate steps as was the case with Almen strip peening. New designs of shot peening equipment with more flexible manipulating systems offer further potentials. The sensor can be placed and reached nearly everywhere in the cabinet. This will permit velocity measurement to be integrated directly in the component peening process during parameter adjustment of each peening step. Thus, process monitoring will be closer to peening and can be performed, including the documentation of measurement values, for each component in real time thus reducing the time consumed overall. A further conceivable step could be the integration of velocity measuring systems in the shot peeing equipment for process monitoring and control to reduce process fluctuations and increase stability.

References

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