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Vacuum-Suction Peening: A Novel Method for Emission-Free Shot Peening

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1 Introduction

Conventional shot peening equipment such as injector or direct pressure blast systems require compressed air of sufficient pressure and volume flow to accelerate the shot material to desired velocities at certain mass flows onto the surface of the workpieces to be treated [1, 2]. A disadvantage of these pressurized systems is that dust which production can not be avoided during shot peening is emitted to the surroundings. Therefore, in applications where the peening treatments cannot be performed in closed chambers, breathing masks and protective clothing need to be worn. In addition, noise levels caused by conventional shot peening treatments are usually high.

The goal of this presentation is to introduce to the shot peening community a novel shot peening machine, the so called vacuum-suction system whose operating principle does not rely on compressed air. This vacuum-suction system has been patented [3] and one of the authors (G. P.) has received the Grant of Innovation in Brandenburg in 1998.

2 Working Principle

Without the need of compressed air from a compressor, a vacuum-generator, e.g., a by-pass compressor, industrial exhauster or piston pump produces a negative pressure relative to the surroundings of the system. The incoming air generates a suction stream which is used to accelerate the shot medium onto the surface of the parts to be treated and also to transport the shot material within the system. Since the entire unit is under partial vacuum relative to its surroundings, there is no emission of dust. In addition, the partial vacuum keeps the noise level of the shot peening operation low.

In order to design a vacuum-suction unit, the characteristic curves of the suction side of the stream producer and of the unit are optimized. Figure 1 illustrates the experimentally determined dependencies of the volume flow on negative pressure for both the exhauster and the unit.

Since these characteristic curves have reversed dependencies on pressure, there is an optimum working point at the crossing of the curves. As seen in Figure 1, preferred working pressures of the vacuum-suction unit are in the range of $35.000 < p_u < 45.000$ Pa (350 – 450 mbar). Depending on nozzle size, the corresponding volume flows are estimated to result in flow velocities of 150 to 280 m/s.

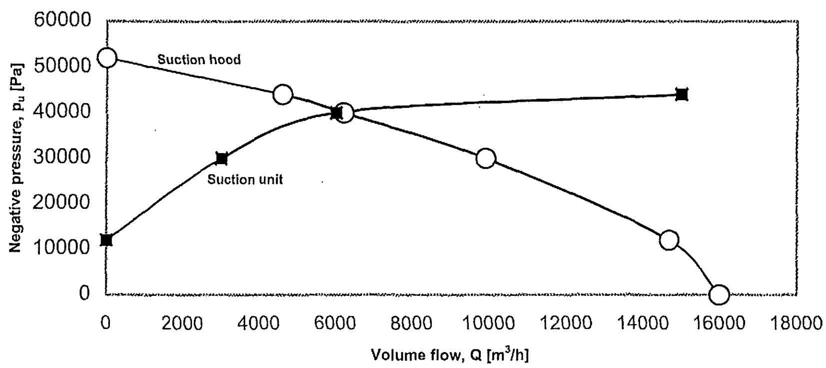

Figure 1: Determination of the working point of a vacuum-suction unit

3 Design of a Vacuum-Suction Unit

The vacuum-suction system was designed to enable sand-blast cleaning even in containers without any particular precaution. There is no emission of dust. Noise transport is hindered inside the vessel. Peening without using a breathing mask is possible since fresh air continuously post-flows due to the sucking action inside the unit. Even in case of leakage or other defects, no dust will be emitted owing to the negative pressure principle.

The system which is schematically illustrated in Figure 2 is a fairly simple technical construction. Therefore, running the unit does not require any particular qualification of the technical personnel. Maintenance consists merely of changing filters and if necessary, replacing worn out parts.

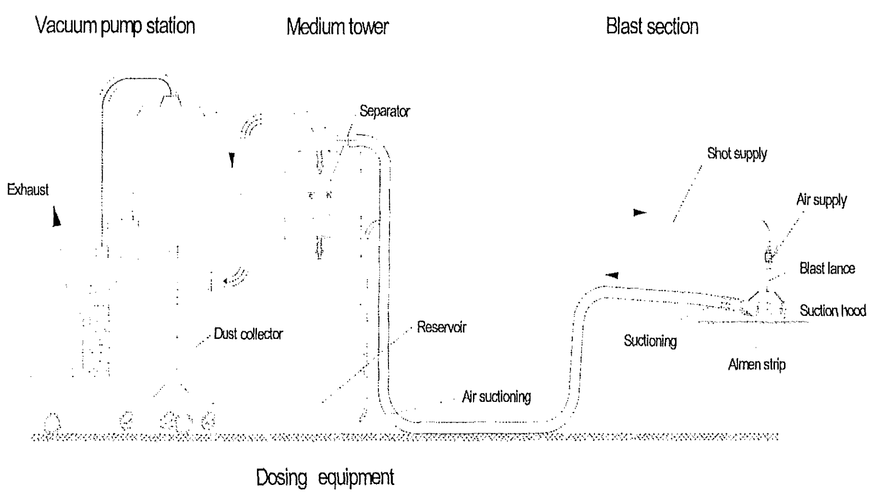

Figure 2: Vacuum-suction system for shot peening (schematic)

The use of shot material is highly economical. Before the air passes through the filter, re-usable shot material returns to the cyclone and then into the process. The air is then cleaned by filters which are adapted to the particular application. Depending on the actual job, the shot material can be used for several cycles. Since its introduction to the market, the vacuum-suction system has been used successfully in a number of different applicationsnt removal on automobile parts and copper conductors

- Paint removal on automobile parts and copper conductors
- Layer removal on galvanized sheets
- Cleaning of railroad axles, metal moulds and insulation parts
- Matte finishing of glass and stainless steel
- Engraving of logos and serial numbers
- Surface roughening before painting
- Descaling of structural parts
- Deflashing of cast aluminum parts, blanks and milled parts
- Smoothening of welds or milled parts

This large variety of possible applications results from the applicability of almost all of the various clean blasting media available on the market. The vacuum-suction system is portable and therefore, can be used in the machine shop, laquering shop or in other locations where dust-free operation is required. The following summarizes the advantages of the vacuum-suction system:

- Emission-free operation even in sensitive environments
- Low cost operation at versatile and flexible applications
- A broad spectrum of possible working media
- No particular effort for precaution
- Fulfills high standards for worker safety and environmental protection
- Easy handling and maintenance through simple construction
- Easily adaptable to various application areas

4 Experimental

While the vacuum-suction system described above is already being used in a couple of different applications regarding mainly cleaning, descaling and roughening jobs, the applicability of this system to typical shot peening procedures has not yet been examined. Unlike the above mentioned operations, in shot peening, round shot is used to minimize erosion effects and to induce cold work and near-surface residual compressive stresses mainly to improve fatigue performance [4]. To examine the capability of the above described vacuum-suction system in typical shot peening applications, Almen intensity measurements were performed using commercially available type A Almen strips. For these measurements, the mobile vacuum-suction system and a standard suction hood were used. An industrial exhaust was used having a power of 5.5 kW, a maximum volume flow of 810 m^3/h and a maximum negative pressure of 42.000 Pa (420 mbar). The following shot materials were used:

- SCCW14 (spherically conditioned cut wire, 0.35 mm average diameter)
- S 230 (cast steel, 0.6 mm average diameter)
- S 330 (cast steel, 0.8 mm average diameter)

After positioning the suction hood, the circle is closed and the shot material is automatically sucked through an asymmetrical suction nozzle. Within the injector peening lance, the pre-accelerated shot material is further accelerated to velocities ranging from 20 to 80 m/s. After hitting the Almen strips, the shot material is sucked off immediately and is directed in the media-tower via a cyclone separator. Any re-usable shot material is separated and can be used several times. Finer particles such as dust and broken shot are removed by the exhaust and retained in a filter (19.500 cm^2 filter area). The noise level of the vacuum-suction system is only 71 dB(A).

The results regarding capability to shot peening are shown in Figure 3 where the arc height of type A Almen strips is plotted versus exposure time.

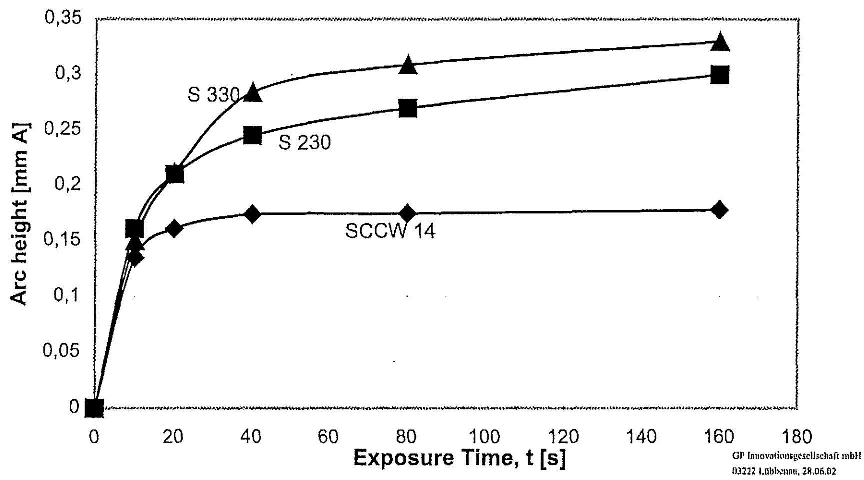

Figure 3: Arc height vs. exposure time in vacuum-suction peening

As seen, there is a clear ranking among the various shot materials with lowest and highest values for SCCW14 and S 330, respectively. These results reflect the differences in kinetic energy caused by the differences in mass being lowest for SCCW14 and highest for S 330. For the given process parameters (16 mm nozzle diameter, 25 mm stand-off distance), saturation in arc height was reached after short exposure times. According to the definition of Almen intensity (arc height increase less than 10 % by doubling the exposure time), the corresponding Almen intensities amount to 0.16, 0.27 and 0.31 mmA for peening with SCCW14, S 230 and S 330, respectively.

Recent results indicate that by using more powerful industrial exhausts, Almen intensities higher than 0.5 mmA can easily be obtained. Thus, it can be concluded that the vacuum-suction system described above can be used in typical shot peening applications where strengthening of the surface regions of structural components by inducing cold work and residual compressive stresses is utilized to improve fatigue performance.

5 Acknowledgements

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6 References

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